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PLANT AND ENTOMOLOGICAL SCIENCES  
II CROP PROTECTION

ANNUAL REPORT OF THE  
NATIONAL RESEARCH PROGRAMS  
1976

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## FOREWORD

### II Crop Protection

Research under Program Element 677 Crop Production Efficiency Research has been divided into two parts. Part II includes research under 9 Crop Protection National Research Programs (NRP) and Part I deals with research under 15 Crop Production NRP's. Each part also includes 2 Special Research Programs.

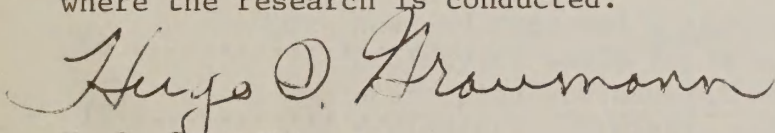
Research included in this section of the report is conducted to improve crop protection technology including biological and chemical methods to control insects, diseases, weeds, nematodes and other pests while at the same time retaining or improving the quality of our environment.

New multidisciplinary concepts for pest management and control include the development and integrated use of conventional pesticides; behavior control chemicals such as pheromones and attractants; genetic techniques, parasites, predators, pathogens and weed-feeding insects; disease and insect resistance in host plants and plant growth chemicals.

The research workers in the Plant and Entomological Sciences publish the results of their investigations in the open literature as quickly as sound scientific judgment warrants. The purpose of this report, however, is to provide for those interested in the results of this work, a brief overview of the scope of the activities and examples of recent findings, some of which still have not been released by publication. No attempt is made at completeness.

This report outlines the research responsible to the Plant and Entomological Sciences Staff and provides a brief description of recent accomplishments at the various locations throughout the United States. The report is organized by ARS National Research Programs, each of which describes a separate subject matter area. The ARS National Research Programs are subdivided into Technological Objectives which more specifically describe the objectives of each area of research.

Readers who have comments or inquiries are invited to contact either the National Program Staff or, more appropriately, scientists at the locations where the research is conducted.



H. O. Graumann  
Assistant Administrator  
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NRP 20220 Insect Control--Horticultural Crops

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RESEARCH PROGRESS

A Insect Pests of Citrus (See also Section B-Tropical & Subtropical Insects)

1 Chemical control. (See also A-8)

Single applications of several juvenoids timed for treatment in the field when most California red scale, yellow scale, citrus mealybug, and Comstock mealybug were in the 1st molting stage provided good control as compared to standard insecticides. Riverside, CA.

Diaprepes abbreviatus reared through the larval stage on artificial diet or on roots of potted citrus plants were parallel in development time and longevity of adults. Increased efficiency in rearing D. abbreviatus has enabled us to have a more dependable supply of insects throughout the year than when we depended entirely on availability of adults from field collections. Heptachlor, carbofuran and OGA 12223 as soil treatments were effective in preventing establishment of neonate larvae of D. abbreviatus on potted citrus plants. An aerial application of TH 6040 in October reduced the reproductive potential of adult weevils caged on treated foliage by 80%. Survivors from 1000 neonate larvae of D. abbreviatus (representing offspring from 1 female weevil) dropped on the soil around a small citrus tree damaged roots severely enough to cause tree decline. Orlando, FL.

2 Biological control. Aphis spiraecola has been successfully colonized on a virus-free stock of diffenbachia; this colony will provide a source of aphids for trials in transmitting several forms of tristeza virus to citrus previously inoculated with mild forms in cross protection studies. Orlando, FL.

Approximately 39,000 Amitus hesperidum cultured under greenhouse conditions at the General Teran facility were released in McAllen and environs during the period November 1975 to June 1976. From April to June 1976, ca. 10,000 A. hesperidum and 1,000 Prospaltella opulenta were shipped from General Teran and released at selected sites in the vicinity of Fort Lauderdale, Florida. The 1st of 5 releases made to date against the citrus blackfly in Florida resulted in an initial parasitism rate of 13%. Weslaco, TX.

Two collecting trips to the region of Cd. Valles, S.L.P. failed to disclose the presence of Eretmocerus serius, the parasite responsible for the initial control of the citrus blackfly in the Caribbean and Central America regions. An attempt will be made to recover this species from the humid areas of Colima, Mexico, for subsequent greenhouse rearing and release in Florida. Weslaco, TX.



Biological studies on the citrus blackfly conducted under field conditions indicate that at least 4 generations occur throughout the year. At an average temperature of 83.0°F (July-Oct.) the mean development period from egg to adult was 65.2 days. A mean of 112 days was required to complete 1 life cycle at an average temperature of 65.7°F (Nov.-March). From July to October 11.8% of the 1st instar larvae completed their development to the adult stage as opposed to 1.2% which developed into adults during the November to March period. Weslaco, TX.

The following number of parasites and predators of soft brown scale and citrus mealybug were released in selected Valley sites during 1976-76:

Microterys flavus (Valley strain) - 800, Microterys frontatus - 650, Pauridia peregrina - 6,000, and Cryptolaemus montrouzieri - 2,800. Weslaco, TX.

### 3 Attractants. (See also Section B-Tropical and Subtropical Insects)

Citrus acreage, in Arizona and California, surveyed by pest control districts, pest management consultants, and growers for California red scale populations by the use of virgin female traps, developed at this laboratory, has increased from 30,000 A in 1974 to 71,000 A in 1975. Riverside, CA.

Annual savings to the growers because of decreased costs of surveys, early detection of pest, and better timed insecticide treatments exceed \$1 million. The number of acres under surveillance as well as added benefits to the growers is expected to increase as the pheromone of the California red scale has been identified and its synthetic compound will soon be available for evaluation and use. The pheromone traps developed for the citrus and Comstock mealybugs are still being used for detection, survey, and monitoring of field populations in California and Texas. A new survey trap for citrus thrips was developed by this laboratory which has been adopted by industry in a limited scale to survey for field populations. Its design allows the trapping of immatures and adults on sticky plates. Immature thrips are caught as they drop from the foliage and adults as they emerge from the soil litter beneath the tree. The traps are rotated under the canopy of the tree at weekly intervals to collect from a new area of soil. The trap's catches are constant and reliable; therefore, it should be an important tool in evaluating the effect of pesticides on thrips. Riverside, CA.

The color response trap was modified to reduce cost while providing the same level of efficiency. Yellow plastic coffee can lids were substituted for the petri dishes used previously. Numerous citrus blackfly finds were made with the trap in previously undetected areas in Texas and in Florida the traps provided distinct advantages in lightly infested areas and equivalent performance with intensive tree to tree surveys in heavily infested areas. It was also found that "Tack Trap" and "Tanglefoot" performed equally well as trap adhesives. "Tack Trap" was determined to be the best material since it was less expensive and more easily handled. Weslaco, TX.

4 Cultural control.

No significant progress at this time.

5 Genetic control.

(See Section B-Tropical and Subtropical Insects)

6 Host Plant Resistance.

No significant progress to report at this time.

7 Disease vector control. The beet leafhopper, Circulifer tenellus, was shown to be capable of transmitting the citrus stubborn disease organism, Spiroplasma citri. This species, collected from the field in several California locations, transmitted S. citri to Vinca rosea, and laboratory-reared individuals transmitted S. citri from diseased to healthy Vinca. Also, S. citri was isolated from C. tenellus collected in Yakima County, Washington, and eventually transmitted to Vinca by Scaphytopius nitridus, the only other known vector of S. citri. The occurrence of S. citri in Washington greatly extends its known geographical range and suggests the possibility that it might cause other plant diseases. Riverside, CA.

C. tenellus was found to naturally harbor and transmit another apparent mycoplasma-like organism that causes rosetting and greening of flower petals in Vinca rosea. It is often harbored by field populations of C. tenellus along with S. citri and the curly top virus. Riverside, CA.

Collections of C. tenellus and S. nitridus from the field further indicated that the stubborn pathogen is widespread and occurs commonly in populations of C. tenellus in the Southwest but is apparently seldom harbored by S. nitridus. Riverside, CA.

The relationship between S. nitridus and S. citri was further elucidated by the demonstration that the species can transmit the pathogen to Vinca after feeding for as short a time as 24 hours; once acquired, the pathogen persists in the body of this species for as long as 86 days with no further access to inoculum. Riverside, CA.

To date S. nitridus has transmitted S. citri from citrus to Vinca, citrus to citrus, Vinca to Vinca, and from Vinca to citrus. Riverside, CA.

8 Integrated control or pest management. During the fourth year of a citrus pest management study cooperative with IFAS personnel, no damaging populations of armored scales, whiteflies, or spider mites were recorded from any of three programs being compared (full spray, modified spray and untreated controls). IFAS cooperators monitored citrus rust mites and a fungus, greasy spot. These two organisms were the most severe

problems associated with fruit production. Twelve chemicals and/or rates were tested in a replicated field test to measure efficacy and length of control of acaricides. SD 14114 50 WP at 8 oz in combination with oil 97% at 1 gal/100 gal provided excellent rust mite control through 12 weeks, but with an infestation level of 26% recorded at 10 weeks. R28627 2E at 16 oz actual/100 gal controlled rust mites through 8 weeks. The same material at 4 oz actual controlled rust mites for 6 weeks. Phytotoxicity at both rates was observed as a burning of late bloom fruit. This chemical burn persisted through harvest time. No burning of foliage or fruit from the regular bloom was noted. Malonoben 1E at 4 or 8 oz actual/100 gal controlled rust mites through 6 weeks. Chlorobenzilate 4E at 4 oz, AC 85258, 25 WP at 2 oz and Cycloprate 40 WP at 4 oz controlled rust mites through 4 weeks. Bay NTN 9306 GEC at 2 or 4 oz actual was effective in controlling rust mite. Orlando, FL.

## B Insect Pests of Tropical and Sub-Tropical Fruit

1 Chemical control. Over 100 dust and aerosol formulations of toxicants and combinations of toxicants were evaluated for insecticidal activity against Caribbean fruit fly adults in semi-trailers and airplanes. Most of the formulations tested gave high initial knockdown as well as 24 hour mortality of flies. Miami, FL.

Liquid proteinaceous food baits show unusual efficiency in dry climates. Screening of several proteinaceous by-products and ammoniacal baits failed to show any consistently superior to Hawaii's standard Staley's PIB-7 + borax + water bait for the oriental fruit fly. Malathion in such baits was repellent raising questions as to its use world-wide in LV baits for control of tephritids. No efficacious extenders were found for the bait formulations. Floridin's Min-U-Gel 400<sup>(R)</sup> shows promise as a non-thixotropic extender for male annihilation formulation sprays while other tested extenders did not show any advantage over the standard Thixcin E<sup>(R)</sup>. Honolulu/Hilo, HI.

2 Biological control. Seven shipments of Opius oophilus were sent to Homestead, FL, to determine whether this parasite could establish in a field population of Caribbean fruit fly, Anastrepha suspensa. Each shipment contained ca. 1000 field-collected females and an equal number F<sub>1</sub> males and females from the laboratory. Field results have been encouraging in that small numbers of O. oophilus progeny have been recovered from samples of fruit collected in release areas in Florida, indicating that released parasites find the new conditions hospitable. Honolulu/Hilo, HI.

3 Attractants. In olfactometer tests to evaluate various chemicals as attractants to fruit flies, cinnamyl alcohol and 3-phenyl propyl ester of cyclohexane carboxylic acid continued to show promise, as did an extract of grapefruit peel oil. Olfactometer studies of various chemicals showed that fly response declined as the flies aged. Also fly response varied dependent upon climatic conditions at the time the chemicals were evaluated. In field studies wild flies did not respond well to these chemicals when tested in McPhail, Steiner or Jackson traps even though laboratory reared flies had responded to the chemicals in olfactometer studies.



Field studies showed that response of wild flies was highest to orange and yellow colored sticky board traps and lowest to blue and dark green. Miami, FL.

In medfly sex pheromone studies, (E)-6-nonen-1-ol, which by itself was shown to be unattractive to male or female medflies in previous outdoor cage tests, was activated by the addition of either of 2 groups of fatty acids associated with the sex pheromone. On the other hand, the activity of methyl-(E)-6-nonenoate, which is known to be attractive to both sexes of laboratory-reared flies, was not affected by the addition of the fatty acids. Samples of cold-trapped condensate of male volatiles which were highly attractive to females in laboratory tests were totally inactive in field tests at concentrations of 5000 male equivalents, whereas a treatment of live males in sticky traps attracted both sexes of feral medflies. Dissections revealed that about 85% of the females responding to the live-male treatment had no eggs in their ovaries, and none had sperm in their spermathecae. When laboratory-reared and "wild" flies reared out of peaches infested in Kula, Maui, were compared for attraction to pheromones in the laboratory, virgin females of both strains responded strongly to the synthetic pheromone. Honolulu/Hilo, HI.

The use of DDVP insecticide in pet flea collar pieces or in Shell No-Pest<sup>(R)</sup> Strips to avoid wire corrosion in the Steiner traps and to lessen accidental toxicity hazards was developed and put to use. Sticky traps were shown to be the most efficient type of detection trap for the medfly while the incorporation of all 3 male lures in a sticky substrate shows promise as a cheap detection trap. Slow-release dispensers such as Conrel's capillary tubes and Hercon's laminated plastic tapes show promise for increasing the efficiency of trimedlure usage in traps. Honolulu/Hilo, HI.

#### 4 Cultural control.

No significant progress to report at this time.

5 Genetic control. Research on the Caribbean fruit fly demonstrated that as flies age their visual acuity is reduced as measured by electroretinograms. Differences in response were also observed in flies produced by larvae reared on various rearing media and between male and female flies. An agar medium used for rearing Caribbean fruit fly larvae was less costly, easier to handle, and easier for disposal than a medium using ground corn cob as a substrate. However, the latter produced more uniform yields of larvae and required less handling. Miami, FL.

The recent invasions of the oriental fruit fly, Dacus dorsalis Hendel, into San Diego and Australia and the Mediterranean fruit fly, Ceratitis capitata (Wiedemann), into Los Angeles and further south in Central America emphasize the need for continued development of early detection and eradication methods to stop the establishment of these and dozens of other potentially damaging tephritid fruit flies in the subtropical continental U.S. The successful completion of the pilot test of sterile Mediterranean fruit flies on

the island of Lanai enables us to give technical advice to the Los Angeles Cooperative Mediterranean Fruit Fly Project on field release and survey and detection systems to enable them to eradicate an incipient invasion of this pest on continental U.S. Honolulu/Hilo, HI.

A total of 600 million sterile Mediterranean fruit flies, Ceratitidis capitata (Wiedemann), were shipped to Los Angeles between October 1975 and May 25, 1976. Mediterranean fruit fly (medfly) pupae were irradiated with 18 krad in nitrogen, dyed with Tinopal SFG or Calco Blue, packed in polyethylene bags, and shipped in styrofoam cartons kept at 12.6-21.0°C. In laboratory tests medfly males treated for releases were ca. 50% as competitive as untreated males; treated males were as attractive to normal females as untreated males; and the mean number of times treated males mated with normal females was 8.7, compared with 12.0 for untreated males. The mean number of matings and mean volume of sperm transferred by medfly males irradiated as pupae dyed and packed in polyethylene bags were equivalent to those of flies treated in nitrogen in the standard manner and about twice those of males treated in air. A new method for holding pupae provided by the Honolulu rearing laboratory for adult emergence and distribution on the ground was developed. Honolulu/Hilo, HI.

Field cage tests show a greater mating ability of the 20-year-old laboratory strain of the Mediterranean fruit fly over the wild strain (over 2:1 ratio). However, when the laboratory strain is irradiated, the ability to mate in both sexes is almost comparable to the wild strain. When the numbers of the 2 strains that do mate are recorded during the time that mating occurs, the reason for the greater sexual vigor of the unirradiated laboratory flies becomes evident. The unirradiated laboratory flies reach a peak mating period 1 hour after sunrise. During that period, a greater proportion of the laboratory population effectively mates while a smaller proportion of the wild flies mates. The broader mating period of the wild flies causes the wild flies to be less competitive in mating with the laboratory flies. However, when the laboratory flies are irradiated, the peak mating period is delayed ca. 1.5 hours as well as broadened, resulting in both strains being comparable in sexual vigor. Marking the laboratory flies with Tinopal dye adversely affects their mating ability. Honolulu/Hilo, HI.

A new method has been developed to determine the effect from gamma irradiation to the testes of medflies used in a sterile release program. The new procedure allows for whole mounting of testes for microscopic observation after the fly has been dead for as long as 2 weeks. Honolulu/Hilo, HI.

Gamma-irradiation doses of 6 and 12 krad applied in air and nitrogen, respectively, produced 99.9% sterility without recovery in male oriental fruit flies, Dacus dorsalis Hendel. A dose of 10 krad in nitrogen caused infecundity in females and 99.9% initial sterility in males, but the latter recovered fertility (ca. 4%) after 6 weeks. Mortalities after 6 weeks were 38% for oriental fruit fly males irradiated in air and 20% for males irradiated in an atmosphere of nitrogen. Honolulu/Hilo, HI.

In laboratory studies on longevity, fecundity, response to cue-lure, and effects from gamma irradiation, the yellow-eyed melon fly, D. cucurbitae Coquillett, was found to be comparable to the laboratory strain. Also, the yellow-eye color shows promise for use as a genetic marker. Honolulu, Hilo, HI.

6 Host plant resistance.

No significant progress to report at this time.

7 Disease vector control.

(See Section A7-Citrus Insects)

8 Integrated control or pest management. Additional studies in El Salvador showed that coffee plantings, a principal host of the Mediterranean fruit fly, were readily identifiable with color IR photography. Coffee planted under an overstory of large trees was readily detectable. Weslaco, TX.

Host plant studies of fruit flies in Hawaii showed that color infrared photography could detect and delimit the distribution of hosts of these important pests. Weslaco, TX.

In connection with the proposal to establish a barrier zone for the medfly in the Isthmus of Tehuantepec, color infrared photography was used to identify hosts of this pest. It was demonstrated that river valleys and farms with fruit crops were primary problem areas in the region. Weslaco, TX.

The auger lure-toxicant dispenser, the viscous lure-toxicant dispenser, and the dispenser of lure-toxicant treated twine were evaluated for control of tropical fruit flies in Hawaii. All three techniques of control show promise and further studies are continuing. Yakima, WA.

Cooperative tests of aerial application equipment developed by the Yakima Agricultural engineering group for the application of thickened sprays, cigarette filter tips, and string pieces were completed on Lanai against the oriental fruit fly as the first step in a pilot test of the integration of male annihilation with sterile male releases. Honolulu, Hilo, HI.

In studies of slow-release formulation potentially useful in large-scale control of fruit flies, encapsulated methyl parathion and encapsulated malathion, each in combination with encapsulated methyl eugenol, showed promise for use against oriental fruit flies. Vitamin E added to the standard larval medium markedly enhances production of pupae in mass rearing of Mediterranean fruit flies and, to a lesser degree, oriental fruit flies. Melon flies affected adversely by lack of hydrolyzed protein to greatest extent soon after adult emergence, but survivors affected to a lesser degree. Mediterranean fruit fly males do not require hydrolyzed



protein to after adult emergence as much as do females. Naked mature larvae of Mediterranean fruit flies survive refrigeration at 40°F up to 3 days; those of melon flies up to 2 days. Musk, astrotone, hibiscolide and phantolide, extenders used in the perfume industry, discovered to almost double the duration of effectiveness of trimedlure as a male Mediterranean fruit fly attractant under laboratory conditions. Honolulu/Hilo, HI.

A multiple aerial release system for dispersing sterile flies was developed and evaluated. The release system consisted of a chute with two 5-inch-diameter motorized saw blades for cutting paper bags and a 10-liter plywood hopper with graduated openings to regulate the flow of pupae. The chute was designed for a single-engine Piper "Cherokee 6" aircraft to distribute sterile flies as free adults, as packaged adults, and as free pupae. Two field tests were conducted to evaluate the release system. For all 3 species, the most effective dispensing method was by releasing free adults. It seems that a pupal release method would be the most efficient since it would involve less handling, but 5 times more flies released as free adults were caught in traps. Even packaged adults did 2-3 times better than flies released as pupae in terms of percent recovered. Honolulu/Hilo, HI.

A total of nearly a billion flies of the 3 species were produced, of which more than 600 million medflies were airshipped to Los Angeles for the Medfly eradication Program. The use of wheat mill feed in the standard larval diet is continued since wheat bran (used by most European laboratories) requires twice the amount of torula yeast for normal development. Honolulu/Hilo, HI.

Raising the larval diet pH from 4.5 to 5.5 increased and gave more consistent larval recoveries. Of the 3 wheat varieties hulled locally, dark hard winter performed best at different pH levels. There is a possibility that spent larval diets could be converted into fertilizer because of their high amino acid content. Previously obtained evidence for parthenogenesis in the laboratory strain of medflies may be invalid as contamination due to incomplete separation of sexes. (In cooperation with the Genetics Department, University of Hawaii) Honolulu/Hilo, HI.

## C Insect Pests of Pome Fruit

1 Chemical control. Preliminary field trials with an experimental insecticide which affects normal molting indicated that this type of chemical may be very effective in the control of codling moth in apples. Vincennes, IN.

2 Biological control. Nosema carpocapsae Paillot has been identified as a common pathogen (97 percent incidence) in mass-reared cultures of the codling moth. Among native populations the incidence of infestation averages 46 percent. Similarly, heavy infestations were found in 82 percent and 1.4 percent of the adult samples among mass-reared and native populations, respectively. Tests conducted to elucidate the transmission of this microsporidian in our laboratory strain included (1) trophic, (2) transemlinal, and (3) transovarial. Feeding spores of this



pathogen to disease-free larvae resulted in > 98 percent successful transmission. Trans-seminal transmission by diseased male parents to progeny was not demonstrated. Transovarial transmission of the pathogen from infected female parents occurred in > 71 percent of the F<sub>1</sub> progeny. Yakima, WA.

3 Attractants. Extracts of Neem tree, *Azadirachta indica*, tested in cooperation with Dr. Martin Jacobson, USDA-ARS, Beltsville, MD, appear promising as antifeedants against codling moth and redbanded leaf-roller. Vincennes, IN.

Ten formulations of microencapsulated (NCR) codling moth pheromone were evaluated in the field as means of disruption communication between the sexes. These formulations differed in treatment of the capsule, concentration of pheromone, solvent system, and/or addition of stickers. The duration of effectiveness of the better formulations approached 20 days, whereas 7 days was the longest effective period previously obtained. Yakima, WA.

Research on a mating inhibitor for control of the codling moth emphasized an effective range of 6 inches with inhibitor-impregnated red rubber stoppers. Each rubber septa was impregnated with 2 mg of (E,E)-8,10-dodecadien-1-ol acetate (8,10-Da) and spaced as evenly as possible throughout pear trees. The trap catches, in traps baited with 10 females/trap, were reduced by 98 percent for seven weeks when the acetate was used. In another test the ethyl ether derivative of 8,10-D was used. The concentration of both the inhibitor and the pheromone was 1 mg/septum. The trap catch was reduced about 80 percent the first three days, then 70 percent the fourth day, and remained in the high-to-mid 60 percent range for the next seven days of the test. Yakima, WA.

Red rubber sleeve stoppers used as substrates for the sex pheromone of the codling moth (8,10-D) produced a first order loss curve ( $k = 1.09 \times 10^{-3}/h$  corresponding to a half-life of 26.5 days); rubber bands produced a complex loss curve; and polyethylene caps allowed extensive chemical degradation after a few days. In field tests, a release rate of 1.25 ug/h produced the highest catches. Sleeve stoppers baited with 2 mg of attractant/stopper had maximum attractiveness for a month and should be ideal for mass trapping during this period. Sleeve stoppers baited with 5 mg of attractant/stopper may be used for survey since the rate loss curve indicates they will be more attractive than the standard survey bait of ten females after as much as 4.4 months (5 half-lives). Several Hercon<sup>(R)</sup> dispensers are under evaluation in the field and appear to be more effective substrates for the codling moth pheromone than are the standard red rubber septa. Yakima, WA.

Four compounds which attract females only and seven compounds which attract both sexes have been found. This may lead to development of effective methods of monitoring female moth activity. Yakima, WA.

#### 4 Cultural control.

No significant progress to report at this time.

5 Genetic control. The treatment of laboratory-reared adult male codling moths with 30 krad of gamma irradiation and their subsequent successful mating with unirradiated females results in an average 4.2 percent egg hatch and 0.42 larvae/mating. The F<sub>1</sub> adults from these crosses are all male and sterile. Yakima, WA.

When one- and two-day old males of the 1962 standard strain (180 generation) and the 1973 strain (30 generations) were irradiated at 5-40 krad, males of the standard strain showed a lower mating propensity than did males of the 1973 strain, except at lower doses (i.e., 5, 10 krad). Irradiated (25 krad) one-day old males of the standard strain passed more spermatophores than did irradiated males of the 1973 strain; 79 percent of the Yakima strain and 74 percent of the 1973 strain mated. Yakima, WA.

A Polish strain of laboratory-reared codling moths showed reduced mating when adult males were irradiated with 30 krad and released in a field cage. Among artificial diet-reared moths and moths reared on thinning apples there were 27 and 39 percent fewer matings than the unirradiated controls. During the 3-day period of field-cage observations for each test, there were no mortality differences between irradiated and unirradiated moths. Also, irradiation had no apparent effect on the hour of mating response. Yakima, WA.

6 Host plant resistance. Sources of resistance to apple maggot and European red mite (ERM) from germplasm available through the cooperative apple breeding program for disease resistance have been confirmed through further testing of material identified as having insect and/or mite resistance in the preliminary tests of 1974. Other germplasm has been identified from preliminary tests as resistant to each of the following insects: codling moth, apple maggot, red-banded leaf roller, plum curculio, and European red mite. We have established: (a) an orchard with clones from parents with potential insect or ERM resistance from our 1974 studies for use in breeding; (b) a nursery of 952 seedlings obtained from 26 crosses between parents identified as potential sources of resistance to insects and ERM; (c) a nursery of clonal material selected in 1975 from parents that showed resistance to insect or ERM; and (d) a clonal planting of the best apple maggot or ERM resistant material on M26 dwarf rootstock in the greenhouse for early season breeding and other studies. Laboratory screening at Vincennes of 112, 133, 126, and 147 lines in a 'free choice' test, and 18, 24, 18, and 13 lines in a 'no choice' test was completed for codling moth, apple maggot, plum curculio, and red-banded leaf roller resistance, respectively; 23 lines were screened for ERM resistance with 6 lines being selected for continued studies. SEM studies have suggested that

resistant selections have lightly pubescent leaves. Losses due to CM, AM, PC, and RBLR in 38662 apples collected throughout the growing season from 176 selections were 13.8, 1.6, 11.9, and 2.2%, respectively. Data relating incidence of apple scab and insect damage has not been analyzed. A 'no choice' test for apple fruit resistance was developed but needs further refinements. Lafayette, IN.

#### 7 Disease vector control.

No significant progress to report at this time.

8 Integrated control or pest management. Field-cage mating of laboratory-reared codling moth is adversely affected by asynchronous photophase entrainment. In one test, the moths were reared from egg to adult under regimes of 1800-2400 or 2200-0400 hours darkness. Field-cage mating by the males was 25.6 percent and 15.4 percent, respectively. In a second test, the dark regimes of two of three groups were shifted from the standard rearing regime of 2200-0400 hours darkness in the late 5th instar larval stage. Among males allowed to remain at the 2200-0400 hour dark regime, field-cage mating was 29.5 percent. Those shifted to 1800-0400 or continuous darkness showed 38.5 percent and 29.4 percent mating, respectively. Yakima, WA.

Preliminary aktograph studies show considerable differences in activity periods when moths of a 180-generation colony, a 30-generation colony, and field natives are compared. Moths of the 180-generation strain were active from 4:00 p.m. until midnight or so. Rarely was any activity recorded after 1:00 a.m. Moths of the 30-generation strain were mostly active during the 4:00 p.m. to midnight period with some sparse and sporadic activity from midnight to 8:00 a.m. Native moths were active from 4:00 p.m. to 8:00 a.m. Some of the natives were inactive during the early morning hours but almost all the native moths were active between 5:00 a.m. and 8:00 a.m. Yakima, WA.

#### D Insect Pests of Stone and Small Fruit

1 Chemical control. Negotiations with Japanese authorities on the acceptance of fumigation with methyl bromide for control of codling moth on sweet cherries are continuing. Additional research shows that low temperature fumigation is feasible and that a package which allows fumigation but helps reduce moisture loss and retain market quality must be developed. NRP 20620. Yakima, WA.

2 Biological control. A species of Euxoa (Noctuidae) infesting a grape vineyard was heavily parasitized by Meteorus leviventris. Two ichneumonid parasites were present in small numbers (Diphyus and Campoletis). Meteorus laphygmae, a parasite imported from South America, is being prepared for release to augment the parasitization of Euxoa species and perhaps other species. TH-6042 gave up to 97 percent control of Euxoa sp. in the field. Western yellowstriped cutworm was controlled in microplots with the



nematode Neoaplectana sp. This nematode has been effective against five species of noctuids in the laboratory. An acceptable pheromone trap for noctuids was developed. A 3-year program of simulated cutworm damage to apple trees had indicated that these trees can sustain a high degree of loss of buds without adverse effect on the crop, i.e., 50 percent bud removal. Three years data has been accumulated on the population trends of several species of noctuid pests. These data will be essential for developing forecasting models. Species identification continues with perhaps 144 species now collected. Some 55 species previously collected were not collected in 1975. Yakima, WA.

3 Attractants. A timing sex-pheromone trap which utilized the trap that was the most effective for capturing male oriental fruit moth, lesser appleworm, and pecan bud moth and was also one of the most effective for capturing male lesser peachtree borer and peachtree borer, was designed and constructed to study response of each species to their respective pheromone sources in the field. As the bait moved from trap to trap each hour, all five species were extremely accurate in seeking their pheromone source. The trap was used to study the influence of temperature on the response of male lesser peachtree borer and peachtree borer to their respective pheromone. Male lesser peachtree response to synthetic pheromone began when temperatures reached 20-22°C with peak activity occurring at temperatures ranging from 25-27°C. Initial response of male peachtree borer was noted at temperatures between 23-24°C and peaked at temperatures ranging from 27-29°C. Byron, GA.

Peak response of male moths (lesser peachtree borers 10:00-11:00 AM; peachtree borer 1200-1:00 AM) (EST) to virgin females and to the synthetic pheromone occurred at the same time. Lesser peachtree borer male response occurred earlier to the synthetic pheromone source than to virgin females; however, the male peachtree borer responded earlier to the female. Byron, GA.

Seasonal distribution studies of the lesser peachtree borer have been studied for several years. A new research tool (i.e. synthetic pheromone) has been used to monitor populations of the species and the pheromone was used to correlate with other methods (pupal-skin counts) to assess populations more accurately under different situations in orchard studies. Byron, GA.

Results of field evaluation of the synthetic pheromone of the lesser peachtree borer has encouraged mass trapping of males for population suppression. Also, air-permeation experiments with the pheromone have encouraged suppression of the population by disruption of orientation of males when they seek females to mate. Byron, GA.

Monitoring populations of both the peachtree borer and the lesser peachtree borer with synthetic pheromone has aided in detection and degree of infestations and in more accurate timing of insecticide applications. Byron, GA.

When lesser peachtree male moths were released in the center of a 2,000 acre (one mile radius) area, 95% of the ones recaptured were caught in traps located within and up to 0.4 mile radius from the release point. Recaptures out to 0.9 mile were common throughout the season. Recaptures ranged from 0 to 42%. Byron, GA.

In tests to determine best types of dispensers for lesser peachtree borer pheromone, it was found that rubber septa out-performed other types of baited wicks, such as metal discs and rubber bands. When captures of males were compared on traps baited with unmated females against those baited with E,Z isomer 3,13-octadecadien-1-ol acetate (the synthetic pheromone), it was evident that pheromone baited traps may out-compete a free-living female for at least 2 months. A trap may be attractive for 4 months in Indiana. Vincennes, IN.

Extracts of Neem tree, Azadirachta indica, tested in cooperation with Dr. Martin Jacobson, USDA-ARS, Beltsville, MD, appear promising as anti-feedants against the lesser peachtree borer. Vincennes, IN.

#### 4 Cultural control.

No significant progress to report at this time.

#### 5 Genetic control.

No significant progress to report at this time.

#### 6 Host plant resistance.

No significant progress to report at this time.

#### 7 Disease vector control.

8 Integrated control or pest management. Trap catches of lesser peachtree borers, in two orchards in which laminated plastic strips (Hercon<sup>R</sup>) strips were used to dispense peachtree borer pheromone (ZZ)3, 13-octadecadienyl-1-ol for disrupting mating communication in the lesser peachtree borer and peachtree borer, revealed that captures of male moths was reduced by 100 percent during the first nine weeks. By the 10th and 11th week, erratic results occurred revealing no difference between the treated orchards and the check orchard. When new strips were placed in the orchards at the end of the 11th week, trap catch again was reduced to 100%. At 10 weeks after the second placement, the strips begin to lose effectiveness. Byron, GA.

Peachtree borer populations were extremely low during the first 11 weeks of the test. Thus, no meaningful results were obtained. However, after recharging the strips on July 10, significant reduction in captures of male moths occurred for 10 weeks in the two treated orchards. Byron, GA.

## E     Insect Pests of Tree Nuts

1     Chemical control. Six foliar pesticides, carbaryl, phenthoate, dialifor, methomyl, acephate, and phosalone, gave 80% or better control of hickory shuckworm when applied on a 14-day schedule beginning with pecan shell hardening. A 7- or 10-day schedule may be required to control the pecan weevil since the most effective foliar materials, carbaryl and dialifor, gave only 85% control with a 14-day schedule. Aldicarb, at 8 lb A1/acre, was the most effective material in preventing bud and foliage damage from pecan bud moth damage. Hot water and hot botran dips at 45 minutes at 125°F to infested chestnuts gave 100% control of chestnut weevil larvae. Byron, GA.

Dialifor and carbaryl were found to be equal for pecan weevil control when applied as 3 sprays at 14-day intervals. Byron, GA.

Dimethoate, dialifor, phosalone, and acephate gave good control as foliar applications against yellow aphid. Malathion was not very effective. Three weeks after treatment, insect predators seemed to influence the aphid population more than insecticides. Pecan weevil larvae (28,500) were put in soil boxes for survival and adult studies. Brownwood, TX.

2     Biological control. The parasitoid Trioxys pallidus was not recovered one year after release at Byron, Georgia. Byron, GA.

Beauveria bassiana spore suspension sprays failed to effect control of pecan spittlebug. Three thousand Coccinella septempunctata were received from Dr. George Angalet at Newark, Delaware, and released in pecan orchard at Byron, Georgia. After one generation the species has increased by 11 times. C. septempunctata has been observed feeding on all three pecan aphid species and has also been observed in pecan trees. Byron, GA.

Compilation of a list of the arthropod fauna of pecan is continuing. Hippodamia convergens has been reared in the pecan orchard on the pecan aphids of hairy vetch and produced roughly 140,000 per acre. As pea aphids become scarce on the vetch, the H. convergens migrate into the pecan trees. Life history studies of pecan spittlebugs are underway. Byron, GA.

3     Attractants. Male pecan bud moths were captured in traps placed in the canopy of pecan trees and baited with 2 µl of (Z)-8-dodecenyl acetate (DDA), a synthetic pheromone of the oriental fruit moth that contained 7% E-isomer and 2 µl of dodecyl alcohol (a synergist). Of 4 trap designs tested, Pherocon 1C Trap, with the bottom and top sections separated, caught the most moths. Traps at 30 ft caught significantly more pecan bud moths than traps at lower heights. The attraction of pheromone for OFM was increased by using a blend of 95% (Z)-8-DDA and 5% (E)-8-DDA in combination with dodecyl alcohol. However, the response of the pecan bud moth was unaffected by changes in the concentration (from 0 to 20%) of the E-isomer. Large numbers of male pecan bud moths were captured during



the spring flights (April-May) in baited Pherocon Traps. However, during the summer and fall flights (June-October), very few male pecan bud moths responded to the baited traps though appreciable numbers were captured in unbaited blacklight (BL) traps. Byron, GA.

Approximately 1,500 male and 1,800 female adult weevils were collected and shipped to the Boll Weevil Laboratory at Mississippi State University for possible pheromone extractions. The factions were returned to Brownwood and tested, but no response was shown by either sex. Approximately 2,500 fall webworm pupa reared on pecan were stored and are being used in pheromone studies. Brownwood, TX.

4 Cultural control. The Ballico test area was increased in size from 9 square miles to 12 square miles with 61 almond growers and 2,600 acres of almonds, 100 acres of walnuts, 1,400 acres of peaches and various host plants around buildings. All work to remove crop residues (mummy fruits) from all these host plants was done during December, January, and February with 9 trunk shakers and a 35-man hand crew. Costs were higher this year than last for hand-crew work, and the trunk shakers and hand-crew were not as effective in the orchard cleanup due to cold-dry weather making it difficult to remove mummy fruits from the trees. Hand-crew costs averaged \$34 for 1976 and \$18 per acre for 1975. Trunk shaker costs averaged \$21 for 1976 and \$23 per acre for 1975. Fresno, CA.

Orchard cleanup in 1975 removed 96-98% of mummys from test-area-almond varieties, and natural occurrences (birds, rain, wind, etc.) removed 50-80% of mummys from check area almond varieties. Blacklight traps caught 6X more moths in the check area than in the test area. Fresno, CA.

Reject-nut-meat figures for the 1975 crop in the Ballico test area were 2.2% for Nonpareil, 3.4% for Merced, and 1.3% for Neplus. Comparable data for the check area were 3.6, 6.4, and 4.5, respectively. In the years 1971-1974, before the pilot test, the test area always had higher rejects than did the check area. Fresno, CA.

The Famoso test area results were 4.0% rejects for Nonpareil and 2.2% for Merced. Comparable for the check were 6.9 and 11.7%, respectively. This yielded a net profit of \$61 per acre or \$23,000 for the 380-acre test block after deducting \$15 per acre for the winter sanitation costs. Fresno, CA.

#### 5 Genetic control.

No significant progress to report at this time.

6 Host plant resistance. Evers, as a male parent in pecan crosses, showed some resistance to hickory shuckworm infestations. Two seedlings were also found to have low infestations. Brownwood, TX.



## 7 Disease vector control.

No significant progress to report at this time.

8 Integrated control or pest management. An interdisciplinary team of ARS scientists here at Byron together with extension specialists from the University of Georgia have initiated a 3-4 year project to develop an integrated program for pest management on pecans. Byron, GA.

The integrated program of pest management initiated in 1975 near Fort Valley, GA, in a 50-acre commercial orchard consists of combining several control methods that have been previously tested through independent research by entomologists, nematologists, engineers, and plant pathologists at the Byron laboratory and shown to be effective in reducing pest damage to pecans. The program consists of (1) blacklight traps for suppressing hickory shuckworm, pecan bud moths, nut casebearer, and certain other lepidopterous pests; (2) a soil systemic insecticide for controlling pecan aphids, mites, and some control of leafminers and pecan spittlebugs; (3) a soil fumigant for control of pecan weevil; and (4) a high fungicide rate at extended intervals for controlling pecan scab and certain other pecan diseases. No foliar insecticides were applied to the pecan foliage in the integrated control orchard. An adjacent 50-acre orchard of the same age received the conventional spray program. Byron, GA.

The results in the first year look promising; however, several years study will be necessary before conclusions can be drawn from the integrated program for pest management on pecans. Byron, GA.

## F Insect Pests of Vegetables

1 Chemical control. Chlorpyrifos continues to be most effective control of those materials likely to be available to home gardeners. Palmer, AK.

Three of 4 systemic insecticides applied to the soil showed promise of control of the western bean cutworm. Kimberly, ID.

Systemic insecticides at planting are effective in controlling aphid populations on potatoes in Maine, but they do not prevent spread of aphid-borne viruses. An electronic system designed to monitor and record the feeding behavior of individual aphids has been used to evaluate the effects of aldicarb and thiofanox on the green peach aphid, the principal vector of potato leaf roll virus. The means of probing time, numbers and duration of ingestion periods, and numbers of ingestions long enough to acquire or transmit the virus were similar for both chemicals. However, aldicarb killed 26% of the aphids after 1 exposure vs. 64% for thiofanox; and aldicarb required 6 exposures to kill 98% of the aphids vs. 3 exposures for thiofanox. Orono, ME.

Of 43 insecticides evaluated for control of the green peach aphid, methamidophos (Monitor<sup>(R)</sup>), oxamyl (Vydate<sup>(R)</sup>), CGA 15324, acephate (Orthene<sup>(R)</sup>), and Bay Hox 1901 all gave superior control of aphids. Of 19 miticides evaluated for control of the twospotted spider mite, monocrotophos (Azodrin<sup>(R)</sup>), propargite (Comite<sup>(R)</sup>), R-28627, and AC 85258 were the most effective. Of 8 insecticides evaluated for control of a heavy infestation of Colorado potato beetle, only methamidophos (Monitor<sup>(R)</sup>) and CGA 15325 were effective. Yakima, WA.

In laboratory and field tests, several chemical compounds showed promise against vegetable insect pests: Methomyl and Mobil 9087 were as effective as the standard naled in killing southern green stinkbugs; Thompson Hayward 6042 and a new synthetic pyrethroid, FMC 3329, gave effective control of the tomato fruitworm; Dimilin (an insect growth regulator) and chlorpyrifos controlled the pickleworm on squash; Mobil 9087, Thompson Hayward 6042, and the Ciba Geigy 15324 appeared promising for controlling the cabbage looper; and best control of sweet potato insects (sweetpotato flea beetle and wireworms Conoderus sp.) was obtained with dyfonate, dasanit, and Bayer 92114. Preplant incorporated treatments of these were more effective than postplant ones. Charleston, SC.

In tests with preplant and/or lay-by broadcast applications of disulfoton (Di-Syston<sup>(R)</sup>) granules and/or disulfoton sprays for control of the green peach aphid on potato, the granular formulation was superior to the spray formulation. In tests with systemic insecticides as in-furrow treatments with potato seed pieces, aldicarb (Temik<sup>(R)</sup>) and thiofanox (Dacamox<sup>TM</sup>) were superior to the other insecticides. None of the treatments were phytotoxic to potatoes. Yakima, WA.

Soil injections and soil drenches of systemic insecticides for control of the spring migrant green peach aphid on peach was not as good as expected, probably because of late application. More work is needed in this area. Yakima, WA.

Of 13 insecticides tested as soil treatments for the control of wireworms, several unregistered materials look promising: N-2596, BAY 92114, CGA 12223, terbofos (Counter<sup>(R)</sup>), and chlorpyrifos (Lorsban<sup>(R)</sup>). Injury to tubers in the check plots increased from 5 percent at 11 weeks after planting to 36 percent at 15 weeks, after which there was no increase at harvest, 5 weeks later. Yakima, WA.

Attempts to control lygus bugs by applying systemic insecticides to bean plants has not been very effective because lygus infest beans primarily after the plants are near or at the bloom stage of growth or after. Therefore, systemics applied at planting time are at least 60 days old at the time of infestation and have degraded, thus foliage applications are more effective. Yakima, WA.

A nomograph was prepared which relates to level of the population of 4th-5th stage alfalfa looper larvae in pea fields to the number of insect contaminants likely to occur in the harvested and processed product. This provides a more realistic basis for the estimating of the population size requiring insecticidal treatment. Yakima, WA.

Considerable progress was made in developing a system for controlling the greenhouse whitefly in greenhouses. Using a device that automatically disperses insecticide, the effect of different dosages of resmethrin applied for different exposures was determined on whiteflies of eight different ages. This knowledge can be used to maintain a whitefly-free greenhouse and to eliminate very heavy infestations. Beltsville, MD.

2 Biological control. This was a year of diverse pest insects in vegetables and fruits including most numerous caterpillar problems in many years. Numerous species of cutworms and other defoliators attacked a wide range of vegetables and fruits. Many of the larvae were heavily diseased and parasitized as few reached maturity in rearing attempts. A cutworm, Sunira verebrata, was one of most spectacular as it not only damaged many plantings but climbed vertical walls and invaded houses. Most of the larvae died (prior to pupation) of disease. Turnip maggot continues to be most widespread consistent problem. Onion maggot primarily a problem in onion sets in contrast to onions from seed. A silphid beetle more destructive to lettuce and young cabbage than in many years. Palmer, AK.

A bioassay technique, based on topical application of infective conidia to green peach aphids, has been developed to evaluate formulations of Entomophthora spores. Computer programs for probit and potency analysis have been prepared and stored for rapid processing of raw data. Orono, ME.

Identification of the aphid pathogen tentatively called Entomophthora nr. thaxteriana is proceeding. Comparisons have been made with isolates of this species from the USSR, Czechoslovakia, France, England, and the U.S., including type material. Our isolate is probably not E. thaxteriana but either E. virulenta or a new species. Orono, ME.

An inexpensive liquid media has been developed that, in 14 liter fermentors, will produce  $5 \times 10^6$  resting spores/ml, equal to our production on solid media. Orono, ME.

The Mexican bean beetle parasitoid Pediobiys foveolatus showed great potential for suppressing populations of the Mexican bean beetle and was also found to parasitize the squash beetle. A Brachymeria spp., probably B. intermedia, was the only parasitoid isolated from weekly field collections of pickleworm larvae and pupae. Parasitism reached 31% by late September. Charleston, SC.



3 Attractants. Extracts of Neem tree, Azadirachta indica, tested in cooperation with Dr. Martin Jacobson, USDA-ARS, Beltsville, MD, appear promising as antifeedants against the striped and spotted cucumber beetle. Vincennes, IN.

Light trap catches of the western bean cutworm showed relatively low populations in 1975, and moth catches were well correlated with later larval damage. Peak moth flight was well correlated with growing degree days. Beans in full bloom at the time of moth flight were most attractive to moths and thus most susceptible to damage. Late developing sweet corn was most subject to damage. Kimberly, ID.

A single multi-baited pheromone trap was found to be effective in surveying more than one insect species. However, looplure in combination with gossypure significantly reduced captures of pink bollworms. In small replicated plot studies, 3 release rates of looplure were evaluated to determine levels of male disorientation and oviposition rates of females on lettuce. Results of this test showed that during the test period there was a reduction in total eggs of 1-, 42-, and 58% from low to high level of release rate compared to the control. However, all 3 rates of pheromone produced a high level of male disorientation to pheromone-baited survey traps. Mesa, AZ.

Tests to discover an inhibitor to reduce the response of male alfalfa looper to the sex attractant of the female resulted in the discovery of a "synergist" which increased sex pheromone-baited trap catches from 3 to 100 fold, initially. Additional tests indicate that it may be possible to quintuple even this rate by altering the ratios and levels of the pheromone-synergist mixture. Yakima, WA.

A female sex pheromone was found in the pickleworm and the melonworm and a flight trap was developed that was effective in trapping pickleworm females coming to cucurbit plantings to oviposit. A method was developed for rearing the pickleworm in sufficient numbers to support host plant resistance and biological control studies. Charleston, SC.

Chemical extracts of flowers attractive to moths were fractionated and one fraction was found to attract the cabbage looper, soybean looper, armyworm, corn earworm, fall armyworm, green cloverworm, crossstriped cabbageworm, and the spotted beet webworm. Genes from wild drosophila were incorporated into a strain with compound chromosomes, which was then placed under varying stresses to better adapt it to outdoor conditions. In competition studies the compound strain was able to replace the wild strain under cage conditions but not when released outdoors in tomato fields. In testing the response of alate aphids to yellow pan traps placed at varying distances apart, it appeared that aphids do not land randomly, as has been conjectured, but that they change their flight pattern over a limited distance to go to the trap. This information on trap efficiency will be of considerable aid in estimating the population size of alate aphids entering a crop. Beltsville, MD.

4 Cultural control. Wheat interplant alone, when viruliferous aphid flight was heavy and early, was found inadequate in protecting cantaloupe against the 'mosaic virus complex' in the Imperial Valley, California. Monitoring of pest insects and parasites in melon plots with and without wheat showed no difference at Brawley field station. At the South Coast field station, increased thrip catches in yellow pan traps occurred. Riverside, CA.

Weeds are usually the early spring host plants of lygus until alfalfa and clovers begin to grow actively. The bugs then disperse to these crops and remain until other seed crops develop during mid-summer. Yakima, WA.

Interplantings of tomatoes and potatoes at different densities and studies of the insect population found thereon showed the relative preference of the insects for the two crops and the effect of the different planting densities on these populations. The insects evaluated were: the potato flea beetle, Colorado potato beetle, pink potato aphid, and the greenhouse whitefly. In many cases low densities of one crop increased the pest infestations on that crop rather than decrease it as was expected. A great impediment to developing control measures for the two species of flies that are major pests of the mushroom industry has been the inability to rear in the laboratory either species. A technique was developed to successfully rear in quantity one of these species. Beltsville, MD.

5 Genetic control. When male and female beet armyworms partially sterilized by irradiation of pupae were mated to F<sub>1</sub> offspring from crosses of similarly treated males to normal females, P<sub>1</sub> ♂ X F<sub>1</sub> ♀ crosses and F<sub>1</sub> ♂ X P<sub>1</sub> ♀ crosses reduced egg hatch over that of controls by 97- and 99%, respectively. Mesa, AZ.

6 Host plant resistance. Approximately 1500 Plant Introduction lines of cantaloupe were screened. Those showing resistance to striped or spotted cucumber beetle are being crossed to domestic lines to create an exotic germplasm pool to be used in further selection. Vincennes, IN.

About 113 domestic varieties are also being screened for the 2 beetles and 2 diseases. Preliminary results indicate some degree of beetle resistance exists in domestic material but resistance to one beetle does not impart resistance to the other. Capability for rearing large numbers of spotted cucumber beetles in the lab has been accomplished and striped beetle rearing work is progressing. Vincennes, IN.

Successive selection and breeding for aphid resistant Cucumis melo advanced two generations. Greenhouse sand pot culture with Ward's solution yielded fruits in 87 days after potting, and complete fruit sets within two weeks were obtained with successive sets of aphid resistant breeding materials. Difficulties were experienced in greenhouse pot culture of plants. These were identified as support media, nutrient mix, an unidentified seed borne virus, and inherent variability among the breeding lines and cultigens. Riverside, CA.

Successive selection and breeding for lettuce resistant to cabbage looper from crosses with Lactuca serriola and L. saligna advanced one generation. Selection technique, using a dome greenhouse, for looper ovipositional preference was completed. Riverside, CA.

Evaluations have been made for possible aphid resistance in 64 cultivars from USDA and Maine potato breeding programs. Comparisons of green peach aphid and total aphid populations in replicated field trials indicated no significant differences from Katahdin variety. Using an electronic monitoring system to record the feeding behavior of individual aphids, 1 of 9 USDA cultivars appears to show some promise on an unfavorable food source for the green peach. Orono, ME.

The cabbage looper is a limiting factor in the production of several of the major fall-grown vegetable crops in the arid areas of Arizona and California. However, the source of the cabbage looper infestations on vegetables in late summer and fall are from host plants other than vegetables. It has been estimated that in a period of ca. 21 days, the cotton acreage in Arizona has the potential of producing approximately  $50 \times 10^9$  adult cabbage loopers. This insect is not considered an economic pest on cotton and is not controlled on this host in usual practice. Therefore, research to develop a pest management program directed against the cabbage looper in cotton to reduce the number of insecticide applications on vegetables appears to be a realistic approach. Results of cabbage looper field population studies on Deltapine nectariless vs. nectaried cotton were as follows: There were 12% fewer males caught, 38% fewer eggs laid, and 22% fewer beneficial insects recorded on the nectariless variety. There was a negative correlation between dates on which high numbers of male loopers were caught and egg and larval populations. In a no-choice greenhouse test cabbage loopers laid 66% and 19% fewer eggs on Deltapine 70100 N and Stoneville 731 N cotton compared to their respective nectaried varieties. There were 19% fewer eggs laid on Deltapine 70100 N and 25% fewer eggs laid on Stoneville 7 A when the two isogenic lines were present in the same greenhouse. When 3 selections of hirsute lines (TM-1) glabrose, normal hairy and pilose, were present in a choice situation, the very hairy pilose had 38% fewer eggs and only 1/3 of the eggs that hatched survived to the 3rd instar. Mesa, AZ.

In field plot studies at Wapato, WA, bean varieties were crossbred with lygus resistant black turtle snap bean and with pinto and red Mexican. These new varieties were all resistant to lygus bug stings to seeds. The big bend bean variety had 21 percent lygus sting injury while all others were less than 2 percent but black turtle which had no sting injury. Yakima, WA.



Sweep net sampling and sticky trapping of lygus showed that all plots had near equal number of lygus, thus it would appear that the lygus are not able to discriminate between these varieties during their dispersal to beans. The varietal differences in pods could enable the lygus bugs to discriminate between pods or differences in stinging could be due to the thickness or texture of the pods. In preliminary tests with lygus confined to pods of black turtle soup beans, the lygus bug was unable to feed on the pods and eventually died, presumably from starvation. Yakima, WA.

Completion of a two-year study indicated that levels of insect resistance in breeding lines of southern peas and sweet potatoes were more effective in preventing insect damage than the most effective registered insecticide. Entries in the regional sweet potato cooperative trials were all more susceptible to insect injury than the breeding line used as a criterion for resistance. Approximately 3,250 sweet potato seedlings were evaluated for resistance to insects in field plots; 45 with acceptable levels of resistance plus other desirable characteristics were retained for further evaluation. Charleston, SC.

Final evaluation of 564 southern pea accessions for cowpea curculio resistance was completed. Three P1's (353383, 354468, 354719) showed appreciable resistance but none were superior to lines currently being used in our breeding program. An inheritance study of the non-preference cowpea curculio resistance factor in southern peas indicated that the factor is not highly heritable. Charleston, SC.

Three hundred cantaloupe accessions were evaluated for pickleworm resistance and 137 snap bean accessions were evaluated for Mexican bean beetle resistance in field plots. No appreciable levels of resistance were detected. Charleston, SC.

7 Disease vector control. One tomato line having edible fruit was found to have moderate resistance to the Colorado potato beetle. This resistance became apparent as the plant matured, young plants being susceptible. Juvenile tomato plants, whether resistant or susceptible, were ingested more by adult beetles than senescing plants. A significant reduction of insecticide applications for control of the Colorado potato beetle was accomplished while still maintaining commercial yields by treating tomatoes with weekly insecticide treatments up to early fruit set. Beltsville, MD.

8 Integrated control or pest management.

No significant progress to report at this time.



G Insect Pests of Shade Trees, Nursery, Ornamental, and Other Horticultural Crops

1 Chemical control. Formulations of extracts of Neem seeds (Azadriachta indica) in concentrations as low as 0.25% completely inhibited adult feeding on leaves of favored food plants. Wooster, OH.

A juvenile hormone (ZR-619) applied to pupae at temperatures of 65-85°F indicated soil temperatures would have to be in the upper 60's for expression of maximum activity. Other hormones have shown activities of from 90-100% following topical applications. Several insecticides were toxic to larvae in field tests. CGA-12223 and Dowco 275 (2 lbs/acre) gave good control under varying climatological conditions. Bay 29114 gave excellent control in preliminary tests. In tests against adults, FMC 33297 and SBP 1513, applied at 0.5 and .25 lbs/acre respectively, reduced feeding damage by 80-100% three weeks after application. Wooster, OH.

2 Biological control. Examination of larvae from several sites showed that 95% of those infected with milky spore disease died in phase IV (massive sporulation). Spores obtained from infected Ataenius spretulus (a scarabaeid pest of turf) were uninfective when injected into larvae. Paraffin-coated, lyophilized cells of Bacillus popilliae were uninfective when fed to 3rd-stage larvae. Wooster, OH.

3 Attractants. Male beetles in the field were not attracted to mixtures of isomers of a synthetic female sex pheromone. The trans isomer alone was inactive, but the cis disrupted searching male beetles repelling 97% from attractive females. This isomer appeared to synergize the attractancy of some chemical lures. Antennectomized male beetles released in the field could not locate attractive females. Wooster, OH.

A season-long test with phenethyl propionate (PEP) + eugenol, 3:7, showed it to be superior to the standard lure, PEP + eugenol 7:3. The new lure is being used in state and federal survey programs. The ability of eugenol to synergize lures was quantitatively determined with several materials. Eugenol increased the attractancy of mixtures over single components by as much as 500%. Of new lure dispensers tested, such as laminated plastic sheeting and hollow plastic fibers, only the APHIS metal can of lure equalled the attractiveness of the standard bottle-wick combination. Increasing evaporative surfaces of lure dispensers containing PEP + eugenol (3:7) up to 6-fold did not repel beetles. A new lure, phenethyl acrylate, was about a quarter again as attractive as the standard. Wooster, OH.

4 Cultural control. Sticky plastic sheets placed under all chafer flight trees (39 small trees) in a 2-acre site for the entire 1974 flight season captured 25,094 chafers. Captures did not reduce subsequent larval populations (fall 1974) or adult populations (summer 1975). Insufficient capture (est. 75% of the total population) and influx from surrounding areas are believed responsible for reduction failure. Geneva, NY.

5 Genetic control.

No significant progress to report at this time.

6 Host plant resistance.

No significant progress to report at this time.

7 Disease vector control.

No significant progress to report at this time.

8 Integrated control or pest management.

No significant progress to report at this time.

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NRP ANNUAL REPORT  
FY 1976

NRP 20230 Cotton and Tobacco Insects

NPS Contact: R. L. Ridgway

PACS Contact: M. T. Ouye

Technological Objective: New and improved methods to reduce losses by insects and mites attacking cotton.

Baton Rouge, Louisiana

The radiation sensitivity of spermatogenic cells in adult boll weevils was determined. Males were irradiated and were then mated to different groups of virgin females on successive days to produce a series of broods. Variations in hatch and progeny development reflected differences in susceptibility of different cell stages to dominant lethal mutations.

Since spermatocytes and spermatogonia are killed by irradiation, one can observe a sharp decline in sperm production about 5-6 days after treatment. This is true for acute irradiation treatments as well as for fractionated doses given every few hours over a period of several days. Fractionated irradiation of pupae causes the greatest reduction in sperm production because a high proportion of spermatogenic cells are immature at this stage of the insect's development; as a result, they are destroyed before they can develop into sperm. Treatments during the adult stage with a single acute dose or with a series of fractionated doses with or without hempen do not reduce sperm production to as great an extent. Nevertheless, these sterilizing agents all have a pronounced effect on sperm production, and consequently reduce the capacity of sterile males to inseminate females. This impairment is especially pronounced if males do not begin to mate until after 5 or 6 days, at a time when no more new sperm are being formed. Under certain conditions, the males are capable of an average of only about 2 good inseminations before becoming aspermic. Sterilizing treatments also have a tendency to reduce the capacity of the males to transfer what little sperm they do have. This is especially true of males given a single large acute dose of irradiation: treated males often survive for an average of 12-14 days, but they are no longer able to mate. These studies of sperm production and mating capacity will enable us to more accurately predict which sterilization treatment will produce the most competitive sterile males.

The mutant "dark-scale" gene in the boll weevil has been determined to be a sex-linked recessive carried on the X-chromosome. When normal males (light-scaled) are mated to dark-scaled females, all resulting male progeny are dark-scaled and all female progeny are light-scaled. The above cross may allow large-scale mechanical sexing of the boll weevil so that only males need be treated and released in an eradication program. Females of the dark-scaled strain are not as productive as those of the normal strain. Males appear to be normal.

The addition of freeze-dried square powder to the adult diet resulted in an increase in progeny development from 34.7% to 70.7%. Outcrossing the original strain to 5 other established laboratory strains resulted in a 47% increase in egg production. However, the strain is still only .6 as productive as the normal strain.

The chemical(s) present in the integument of Heliothis larvae which stimulate(s) females of Eucelatoria species to oviposit have been partially purified. The bioassay using Heliothis cuticles extracted with chloroform-methanol has been improved. Although several different artificial substrates were tested, the development of an artificial cuticle has not been successful. At least two chemicals are involved and both must be present simultaneously for oviposition to occur. The two chemicals have very different solubilities in chloroform-methanol and the absence of the chloroform-methanol insoluble chemical explains the failure of the flies to oviposit on artificial substrates treated with chloroform-methanol extracts of Heliothis cuticles.

Some work has been done on the collection, storage, and purification of the volatile chemical(s) from cotton and okra attractive to Eucelatoria species females. Although okra was attractive at all times that it has been tested in the summer, tests in late May when the weather was unusually cloudy and cool in the mornings showed that production of the attractant from okra was dependent on bright sunlight and warm temperature.

Female Eucelatoria species are infected with a pathogen that causes the females to have shorter longevity than males and results in a plugged uterus in older females not previously exposed to their hosts for parasitization. Antibiotics are being fed to adult flies to control the uterine infection and are effective in controlling the pathogen in maggots held on artificial diets. The effects of the pathogen are minimized by not crowding the adult flies. Chloramphenicol fed to adult Archytas marmoratus markedly increased their longevity and demonstrated that this antibiotic probably was a major factor responsible for the significantly increased survival of adults obtained in uncontrolled tests several years ago.

#### Brownsville, Texas

Trap studies showed that boll weevils could be caught all weeks of the year. Weevils were found in ground trash in the fall and winter of 1975-6. Most weevils were found in hackberry and granjero habitats. Among the insecticides tested for control of boll weevils, the pyrethroid, FMC-33297, showed effective control at 0.1 lb/acre. The insect growth regulator, Dimilin (TH-6040), reduced  $F_1$  populations of boll weevils 60% in field cages; another growth regulator, Altozar (2R-512), prevented any larvae from emerging from squares. Chemical termination studies showed that a combination of chlorflurenol and 2,4-D effectively controlled square development of cotton, despite rainfall, and did not reduce yields when applied 35 days after flower. Ninety percent open bolls occurred 71 days after first flower, thus this treatment prevented square development for about 2 generations of boll weevils.

Field cage tests showed that the insect growth regulators, Dimilin (TH-6040), Altozar (2R-512) and May and Baker 52148, effectively reduced numbers of large larvae of the tobacco budworm.



Dispensers for tobacco budworm female sex pheromone (virelure) were developed and tested at 14 locations throughout the Southern United States at State and USDA research centers. Wild male tobacco budworms were caught, and populations were surveyed at all locations. One location reported catching more than 27,000 males in 11 traps during the growing season. A dispenser was developed that remained attractive for at least 2 weeks and was competitive with living females as bait in survey traps.

A comparison of the effectiveness of sticky traps containing virgin females with similar traps containing virelure at 50-250 yd from a tobacco budworm release area showed that the effectiveness of the traps containing the virgin females was reduced by 75% at 250 yd and that the effectiveness of the traps containing virelure was reduced by 91% at the same distance.

Experiments in field cages showed that one of the two female sex pheromone components (C<sub>14</sub>-Z-9-TDAL) interrupted male courtship behavior significantly more than the other component (C<sub>16</sub>-Z-HDAL) or a combination of the two components. The single component offers great potential as a "confusant" and control agent for tobacco budworms.

A pheromone was extracted from male tobacco budworms that suppresses emission of sex pheromone by the female. The chemical(s) was collected from male hairpencils and genitalia and bioassayed with females to test its effect. The male pheromone has not yet been isolated or identified from chemical extracts.

Nutritional studies with the tobacco budworm indicated that the blue-green algae, Spirulina geitleri de Toni, could be used with great success as the protein in larval diets. Spirulina has a protein content of 70% (as compared to 32% for wheat germ and 50% for soybean flour). A level of 3% protein is preferred in this diet; thus 75 g of Spirulina can substitute for about 196 g of the other protein sources at a significant reduction in cost of the diet.

Other studies have shown that a soybean flour larval diet containing 3% protein, 5% carbohydrates, and 0.65% lipids, and with wheat germ replaced by wheat germ oil or corn oil was more efficient and less expensive than the standard wheat germ-soybean flour diet. Insects reared on this new diet produced heavier and equal yields of pupae, greater yields of adults, and a greater mating frequency and number of eupyrene sperm/mating than insects reared on the standard diet. Increasing the protein percentage to 6-9% in the larval diet increased the number of eggs laid/female.

Tests showed that furcelleran could be used in place of agar as a gelling agent in the tobacco budworm diet; however, Kelco gel HV<sup>(R)</sup> delayed development and resulted in smaller pupae. Further tests indicated that deletion of gelling agents and using corn cob grits as a filler to form a paste had no detrimental effects on growth or development.

Studies comparing eupyrene sperm transfer by the standard laboratory culture of H. virescens, by the laboratory culture reared one generation on cotton, by wild H. virescens, and by wild H. virescens reared on artificial diet for one generation showed that wild males transferred 2.5 times as many sperm as the laboratory males. Furthermore, the laboratory males reared on cotton in field cages transferred 115% as much sperm as laboratory-reared males, and the wild males reared in the laboratory one generation transferred 73% more sperm than the standard laboratory males.

Flight mill studies indicated that adult irradiation (30 kr) had no effect on the flight ability of male tobacco budworms. However, the age of the male (irradiated or unirradiated) was observed to affect flight.

Females reared as larvae on diets containing reserpine or quercetin as chemosterilants were significantly less attractive to males than either untreated females or females reared on diets with sulfanilimide, DL-leucine, bis dicumarol, dichlorophenoxy acetic acid, sitosterol, or dihydrocholesterol. Treated females were used as bait in pheromone traps to determine relative attractiveness as indication of pheromone production.

Studies on the effect of distance on peak mating periods of released laboratory reared H. virescens showed that when male and female moths were released 300 yd apart, their peak mating activity occurred at the same time as when they were released together in the same area. However, separation by 500 yd resulted in a 2 hour delay in the mating peak.

#### College Station, Texas

The efficiency of techniques used to mass produce an egg parasite (Trichogramma pretiosum Riley) for field release was increased ca. 65% with the addition of a new type of oviposition cage. Since host egg parasitism is increased greatly in the new cage, fewer insects are required for breeding stock. Labor required to service the new cages is reduced ca. 30%.

Technology for mass production of the predator Chrysopa carnea Stephens was improved with the development of a new disposable and more compact (by 50%) rearing frame. Required feedings were reduced from 5 to 4 and production usually exceeds that obtained by previous methods.

In research to improve methods used for inundative releases of Trichogramma spp. on field crops, spray applications of suspensions of free parasitized eggs of Sitotroga cerealella (Oliver) in different liquids provided good coverage on plants but the adverse effect of formulation materials severely reduced parasite emergence. More recent preliminary tests indicate that Trichogramma spp. parasitized eggs can be distributed effectively and have a high rate of survival when attached to wheat bran with a dilute mixture of mucilage and water and applied with a modified seeder mounted to a motor-driven fan.

Certain behavioral characteristics of native adult Chrysopa carnea Stephens were found to follow a diel periodicity in the field. Peak activity periods were: feeding 7-8 PM, mating 8-10 PM, and oviposition 9-10 PM. Adults were inactive from 9 AM to 6 PM.

Tests in field cages of cotton indicated that a single application of the insect growth regulator TH 6040 at a rate of 0.25 lb/acre had no apparent effect on the parasitization of tobacco budworm eggs by Trichogramma spp. However, the same treatment had an apparent adverse effect on Chrysopa carnea Stephens larvae; mortality averaged 88% among larvae in treated cages and only 21% in the control.

Of many experimental insecticides tested for effectiveness against Heliothis spp. and the boll weevil, greatest topical toxicity (150X and 10X more toxic than methyl parathion against tobacco budworm larvae and adult weevils, respectively) and residual insecticidal activity on treated cotton plants in a greenhouse were obtained with synthetic pyrethroids RU-22950 and RU-22974 from PROCIDA. Replicated field tests, comparing synthetic pyrethroids [FMC 33297 (FMC Corp.), SD-43775 (Shell Development Corp.), AC-206797 (American Cyanamid Co.)] applied at rates of 0.1 and 0.2 lb/acre and an organophosphate (BAY NTN 9306, Chemagro Corp.) at 1.0 and 1.5 lb/acre for control of Heliothis spp. on cotton, demonstrated that 0.1 acre plots treated with 0.2 lb/acre of SD-43775 yielded significantly more seed cotton than all other plots including those treated with a standard mixture of methyl parathion, toxaphene, and chlordimeform (1.5, 0.75, and 0.125 lb/acre).

The fate of foliar-applied insect growth regulator TH 6040 (radiolabeled with  $^{14}\text{C}$  at 2 positions in the molecule) on cotton was determined by radiometric procedures. After manual treatment of individual leaves with an aqueous suspension of a wettable powder formulation of the chemical, absorption was very slow; 87.4% remained on the leaf surface after 14 days, 4.8% was in the internal extract, and only 0.5% was found in extracted residues of tissues. The only radioactive material detected in external or internal extracts was the parent compound.

The chemicals in frass of boll weevil larvae, which elicit an ovipositional response by the parasitic wasp, Bracon mellitor Say, were isolated with a combination of column, thin-layer, and gas-liquid chromatography. Derivatization, analytical tests, and mass spectrometry were used to identify the biologically active materials as long-chain fatty acid esters of cholesterol. Bioassays of both natural and synthetic cholesteryl esters were used to confirm activity. Other studies demonstrated that ovipositional responses could be elicited by the hexane and chloroform-methanol fractions of feces from boll weevils reared on artificial diets. The active component was identified as methyl-p-hydroxybenzoate (methyl parasept), a mold-inhibiting additive. Certain studies suggested that the parasitoid response to methyl parasept was associatively learned and that it decreased with time in the absence of reinforcement. Studies of the fate of foliar applications of  $^{14}\text{C}$ -labeled synthetic pyrethroid AC-206797 on cotton in the field demonstrated the formation of at



least 11 decomposition products; 2 major products, representing 6 and 11% of the dose, were identified via gas chromatographic-mass spectrometry techniques. The half-life of radioactive materials on leaf surfaces was ca. 5 days.

Promising new protective formulations of the Heliothis nuclear polyhedrosis virus were evaluated for persistence and efficacy in the field. Bioassays of plants treated at practical rates indicated that 2 encapsulated and 1 liquid formulations (prepared in cooperation with Southwest Research Institute, and containing carbon black or titanium dioxide to provide shielding from ultraviolet light) were much more persistent (>10 days) than available commercial formulations (<2 days). Replicated tests in the field indicated there were no differences in yields of seed cotton among plots treated with the aforementioned virus formulations or with a standard insecticide mixture; yields of all treated plots were significantly greater than those of untreated plots.

Laboratory evaluations of a number of new encapsulated formulations demonstrated that inexpensive types of carbon black could be used without any loss in protection. Formulations made with zinc oxide were not as good as those made with titanium dioxide. Seventeen lb of encapsulated formulations of the Heliothis nuclear polyhedrosis virus were prepared and sent to the Cotton Insects Research Laboratory at College Station, Texas, for evaluation in the field against Heliothis spp. pests of cotton during the 1975 growing season; 14 lb were made with carbon black as the ultraviolet light (UV) screening agent, and the balance was made with titanium dioxide. Encapsulated formulations made with 3 types of zinc oxide and 13 new types of carbon, and others with different levels of UV protectants or synthetic feeding stimulants were prepared for laboratory evaluation.

#### Florence, South Carolina

In an early season field test, an insect sterilant Dimilin was applied in 0.5 gal invert sugar with 0.15 to 0.3% Kelzan adjuvant at rates of 1, 2, and 4 oz/acre. First applications were made on June 17 on 4-6 acre fields already squaring and infested with boll weevils. Egg hatch from treated plants was reduced to zero after 6-13 days feeding. It appears that pre-squaring applications of Dimilin could effectively supplement and reinforce the effects of sterilized male boll weevils released in the boll weevil eradication program.

In small cage field tests, Ciba-Geigy CGA-15324, FMC-33297, Procida RU-19053, RU-21435, RU-22366, and RU-22950, Rohm and Haas RH-218, Shell SD-41706, and SD-43775, Stauffer Sumithion, and Thompson-Hayward TH-6042 showed promise against the boll weevil. In topical tests, the 48-hr LD<sub>50</sub> values for FMC-33297, RU-22090, malathion, and methyl parathion were 0.17, 0.09, 0.93, and 0.5 µg/weevil, respectively.

In 5 separate field tests, treatments were evaluated primarily for boll weevil and bollworm spp. control. Treatments were applied conventionally with Delavan Raindrop nozzles and as sprayable baits. The treatments included experimental insecticides, biologicals, and experimental rates of recommended materials with and without chlordimeform. Of the experimental materials, FMC-33297, Shell SD-41706, SD-43775, and the Raindrop nozzles showed promise against the boll weevil.

In a plant growth regulator experiment designed to prevent a source of food for boll weevils and bollworm spp., the general magnitude of amount of regrowth of leaves and squares was as follows: 1 application of Pennwalt TD-1123 > untreated control > 2 applications of TD-1123 > 3 applications of EM Laboratories chloroflurenol > 3 applications of TD-1123 > 2 applications of TD-1123 + chloroflurenol.

In field tests with various materials, FMC-33297, Bolstar (BAY NTN-9306), Shell SD-41706, and SD-43775 were the most effective. Raindrop nozzles provided control equal to conventional nozzles, but yields were poor. Methyl parathion and toxaphene + methyl parathion with added chlordimeform (0.125 lb) produced more seed cotton than without chlordimeform. The Heliothis nuclear polyhedrosis virus Sandoz SAN-240 WP (Elcar) + SAN-285 adjuvant, SAN-240 WP + invert sugar, and Dipel + cornmeal bait provided poor bollworm spp. control.

In cage tests, Chevron acephate, BAY NTN-9306, Ciba-Geigy CGA-15324, FMC-33297, Procida RU-19053, RU-22366, RU-22950, Rohm and Haas RH-218 + toxaphene, Shell SD-41706, SD-43775, Sumithion, and Thompson-Hayward TH-6042 showed promise against the bollworm spp. In topical tests, the 48-hr LD<sub>50</sub> values for RU-22090 were 0.0080 and 0.0087 µg/larva for H. zea and H. virescens, respectively.

In cage tests, Chevron acephate, BAY NTN-9306, Rohm and Haas RH-218, Shell SD-41706, SD-43775, and Thompson-Hayward TH-6042 showed promise against the beet armyworm. In field tests, Cacomox 10G, carbofuran 10G, and aldicarb 15G applied infurrow or hill-dropped indicate no difference in thrips control, stand or yield.

Egg deposition and fertility and oviposition periods of female boll weevils taken from woods trash and fed on cotton squares were significantly increased when they were confined with 1 or 2 male weevils. Male weevils were also found to live longer than females.

A field cage study of boll weevil generations initiated from overwintered weevils indicated 4 and possibly 5 generations were possible in the Florence, S.C. area.

Sixteen thousand three hundred seventy flared and fallen cotton squares examined weekly for boll weevil parasites produced 35 Nealiolus rufus (Riley), 3 N. curculionis (Fitch), 2 Bracon mellitor Say, and a number of Proctolaelaps bickleyi (Bram) mites. In addition, only 25% of the squares produced weevils.

Using soil boxes containing 3 different soil types and 4 different rainfall rates, successful emergence of bollworm and budworm moths was related more to the existence of a naturally formed pupal tube and cell than to soil type or rainfall.

In a non-competitive test, it was determined that one 3-mg grandlure wick on a cotton plant was as attractive to female weevils as one male boll weevil that had been feeding on a cotton square.

A Sonoco Products Co. live trap which was very effective in capturing boll weevils in early season became ineffective in mid to late season.

Tree Tanglefoot mixed with Saturn yellow pigment and sprayed on cotton plants was ineffective in holding weevils that landed on the sticky surface.

Two grandlure formulations, Hercon L-64-44-7 at 30 and 40 mg grandlure per waifer and 40 mg of grandlure in a filter were effective for about 6 weeks.

The majority of weevils responding to a grandlure-baited red trap altered their path to go to an unbaited Saturn yellow trap when it was only 6 ft away. About 40% of the weevils were captured in yellow traps 12 ft away but yellow traps 18 ft or more away from the lure had little effect on weevil response.

In a competitive test, the Saturn yellow trap with grandlure captured 70% to 90% of the responding weevils when compared to a red trap with grandlure at various distances, but in a non-competitive test, the percent capture by the yellow trap ranged from 51% to 79% with a mean 60% recapture.

The percent recapture of marked laboratory-reared females was the same (28%) when red and yellow traps or only red traps were baited with grandlure.

A locomotor test and stress test were devised to evaluate the quality of lab-reared weevils. It was determined that weevils reared on 2% sugar diets were more susceptible to stress and produced fewer eggs than those reared on diets with 4% sugar.

#### Mississippi State, Mississippi

Cotton and Insect Products. A bacterial suppressant for Bacillus thuringiensis has been isolated from cotton buds. Attempts to identify it are in progress. The production of the male boll weevil pheromone is higher when insects are fed cotton buds than when they are fed artificial diet, and decreases in pheromone production occur when insects are fed chemosterilants. The production is higher in summer than in winter. It varies on a daily cycle with the highest production at 10 AM each day. Bacterially contaminated insects produce less pheromone. Crop growth models have been constructed in cooperation with plant physiologists relating plant nitrogen and carbohydrate to organ age. Cotton plant volatiles were collected daily in the field and it was found that the volatiles output reached a high in early August at the



period of highest bud count. This period coincides with the observed time of migration of boll weevils. Work towards a goal of developing improved larval and adult diets was conducted. Procedures were worked out in cooperation with the rearing entomologist to analyze and compare the amino acids of insects in their life stages and diet protein. Adjustments in the protein content increased egg production. In work to identify the female boll weevil pheromone, 2 components were identified that in combination with other fractions, elicit a laboratory response. Studies with diapausing boll weevils showed that the lipid content did not decrease measureably until near the end of that period. The lipid content of non-diapausing bacterially infected insects was reduced as much as 67%. The surface lipids of glabrous cotton were found to contain hydrocarbons, alcohols, sterols, and other triterpenoids. The surface lipids are believed to contribute to plant resistance against insects and diseases.

Biology and Behavior of Cotton Insects. Data on long-range dispersal of the boll weevil has been more completely analyzed further suggesting buffer zones in eradication trials with widths considerably greater than the 45-mile maximum distance of observed weevil movement. Sterile male weevils may be 50% competitive with normal males in some programs of rearing and sterilization. Males treated with 10,000 rads of CO-60 gamma irradiation may produce equivalent amounts of pheromone as control weevils for 5 days. Normal overwintered males produce less pheromone with the ratio of the components grossly unequal to the optimum. The Leggett (live) trap is much more selective for the boll weevil than the equal sized Whittam (sticky) trap. A sticky trap (Jackson) swinging on a string caught more weevils than the same trap stationary on a stake.

Integrated Control Measures. Thompson-Hayward 6040 (Dimilin) suspended in raw cottonseed oil and applied as a foliar spray was highly effective in preventing hatch of boll weevil eggs in laboratory and field tests. In a field experiment on an isolated cotton acreage in western Arkansas, season-long foliar sprays of Dimilin suspended in cottonseed oil suppressed the field population by 99.9%. In an in-field trapping experiment, 20 in-field traps captured 79% of the emerging overwintered boll weevil population from May 20 to July 20. Nine azinphosmethyl applications at 3- to 6-day intervals from July 29 to August 28 + 20 in-field traps/acre did not eliminate an isolated reproducing population of boll weevils.

Mass Rearing and Sterilization. The use of fractional dosages of gamma irradiation appears to be a successful method of attaining sterility in the boll weevil. Indications are that the success achieved in small-scale laboratory tests with boll weevil pupae will be repeated on a large-scale basis as evidenced by preliminary results attained in cooperative studies with the University of Tennessee Comparative Animal Research Laboratory at Oak Ridge. The study on the mode of action of Dimilin showed it to be a male as well as female sterilant, albeit to a much lesser extent. In addition to its reported mode of action as a chitin synthesis inhibitor, it was found to be an inhibitor of the biosynthesis of DNA in the female weevil. It was also found to inhibit testicular growth. No inhibition of RNA or protein

synthesis was demonstrated. Progress was made on the development of diagnostic tests for the evaluation of health, vigor and sterility in the weevil. In the respirometry tests, base lines of respiratory function were developed and correlations were made between oxygen uptake and pheromone production. Sugar added to the larval diet has increased the longevity of sterilized boll weevils. A number of candidate chemosterilants were found effective against either male, female or mixed sexes.

#### Phoenix, Arizona

From 1.8 to 0.9 percent of cotton blooms were found infested by pink bollworm larvae during early July. The daily percentage decreased from 16 percent at the beginning of July to less than 1.0 percent at the end of the month. The percent of infested blooms decreased as the number of blooms per acre increased. Larvae collected on blooms pupated 4.53 days after flowering. Almost all larvae left the flowers the day after flowering between the hours of 10:00 AM and 1:00 PM. The pupal stage was 7.29 days in the field. About 40% fewer infested flowers made bolls but the weight of bolls developed from these flowers was not affected.

Detailed studies were made of the growth of cotton plants with various environmental factors. Field populations of pink bollworm, development of the different stages in relation to temperature, initiation of diapause in relation to temperature and day length, and the breaking of diapause in relation to temperature and moisture enabled the development and evaluation of a computer simulation (KOTTON) to model the cotton plant and the pink bollworm population, in cooperation with A. P. Gutierrez of the University of California, Davis.

Results of pink bollworm pheromone trap density studies indicated that when total numbers of males captured did not exceed ca. 25 moths/ha/week, a density of 2.5 traps/ha (=1/acre) was optimum. When catches increased to a range of 150-400 moths per ha/week, a density of ca. 12 traps/ha was optimum. Approximately 48 gossyplure-baited traps ha were used in a male annihilation study on 36 ha (11 fields) of cotton during the period April 29-September 15, 1975. Nine percent of the acreage attained 10 percent or greater boll infestations during the season compared to 45%-100% for the preceding 1972-74 seasons. Early season catches indicated that male moths congregated in cotton fields regardless of where they emerged.

Strains of pink bollworms selected in the laboratory for the inability to respond to artificial environmental conditions which induce diapause in non-selected strains did not respond to natural diapause-inducing conditions. The natural conditions were experienced in an outside insectary exposed to natural temperature changes over the period of October 1 to April 1. Native larvae under these conditions diapaused at rates ranging from 81% to 94%. Response to the selected strains ranged from 0.0% to 21.0%. The genetic inheritance of the non-diapause trait is dominant to the ability to respond to diapause-inducing conditions but the trait is inherited as a quantitative trait rather than a simple Mendelian trait. Genetic crosses and further selections have enabled us to mark the non-diapause strains with the morphological mutations orange eye, violet eye, black-body color, and dark eye.



Violet eye is a sex-linked recessive marker, orange and dark eye are recessive autosomal mutations, and black body is a dominant autosomal mutation.

Previous research indicated that pink bollworm larvae could be irradiated at low doses of radiation to produce sterility. Larvae were irradiated at 2 and 4 krads, allowed to pupate, and then released as adults into field cages where natural populations of pink bollworms were growing. The test contained 4 replications of a control where no adults were released, plus 4 replications of releases of either 2 or 4 krad treated moths. Neither treatment was successful in controlling the normal population growth of the untreated insects.

Release of pink bollworm adults which were irradiated as larvae at 2000 or 4000 rads failed to control natural populations of pink bollworms in field cages.

The amount of diet required to rear pink bollworms was reduced by adding inert fillers to the shredded diet. The best filler was polystyrene foam beads. Mixing the beads with an equal volume of diet provided an adequate rearing media. The beads are lightweight, do not compact, do not absorb moisture, and cost one-twentieth as much as an equal volume of diet. After five generations, no adverse effects due to the beads were detected. The next best filler was shredded urethane foam. This foam plus diet produced more insects per rearing container, but mold and yeast developed in many of the containers. Since the mold and yeast occurred after larvae started to cut out of the containers, the combination of moisture, frass, and urethane foam must have provided a better environment for this type of organism. Additional reduction in diet cost was obtained by substituting gelcarin for agar. Gelcarin may cost one-half to one-fifth as much as agar depending on relative demand. The higher gelling temperature of gelcarin makes preparation and handling more critical. Also, gelcarin-based diet has slightly more surface moisture after shredding than agar-based diet.

Stoneville 731N (nectariless, hirsute), Stoneville Sm [W74-4-153] (nectaried, glabrous), and Stoneville ne,sm [LA 15,213] (nectariless, glabrous) harbored significantly fewer pink bollworms in green bolls than the regular St 7A, and all had lower percentages of damaged seed. Stoneville ne,sm had 64% fewer pink bollworms in green bolls and 57% less seed damage than did the normal Stoneville 7A cultivar.

Two additional cottons developed by G. A. Niles, Texas Agricultural Experiment Station, have reduced pink bollworm numbers in field trials. One type is an early maturing, determinant line (1X6-56) which had 43.1% less damaged seed and 38.8% fewer pink bollworms per 1000 g boll weight than the DPL-16 check variety. The other line (AET-5X(108XBr-2)-7-69) had 41.5% less damaged seed and 51.9% fewer pink bollworms per 1000 g boll weight than the check variety.

In a test of 23 Gossypium barbadense cottons, three lines having no glands or reduced glands (monomeric) had approximately 20% fewer damaged seed than did the Pima S-5 check variety.



The number of pink bollworm larvae in bolls (season average) was reduced by 64% and the percent damaged bolls reduced by 57% when a nuclear polyhedrosis virus was applied to field cotton in a bait formulation. Applying the virus in water suspensions did not significantly affect these parameters. The feeding stimulant formulation decreased the number of newly hatched larvae that enter bolls when the larvae had to travel from the plant terminals to the bolls. Results indicated that bait formulations were more effective during the first half of the growing season.

A new, less costly, and simpler bait formulation was developed that increased the effectiveness of a nuclear polyhedrosis virus in greenhouse tests against the pink bollworm and the tobacco budworm. The new bait may be applied as a dust or as a wettable powder. Mortality of budworms after a 2-hour exposure on cotton treated with virus alone was 33% compared to 93% when the same virus was applied in the new formulation.

Although tests are incomplete, studies have indicated that new methods developed for the in vivo production of the nuclear polyhedrosis virus of the alfalfa looper will require less handling, and thus be less costly than previous methods. Approximately 60,000 L. E. (larval equivalents), or  $3.6 \times 10^{14}$  polyhedral inclusion bodies were produced to be used in efficacy testing of this virus.

Numbers of pink bollworm larvae in the field were shown to be significantly correlated with fluorescent lint and fluorescent cotton seed, an indication of the presence of aflatoxin.

A morphological study of the nerves and muscles that control the ovipositor and oviduct of the female pink bollworm moth has been completed. Initial electrophysiological experiments have indicated that two types of electrical events are associated with the spontaneous contractions of the muscles of the common oviduct: (1) post-synaptic or junctional potentials which are found close to the nerve muscle junction, and (2) action potentials which arise spontaneously from the muscle fibers themselves. The relationship of both of these events to the process of egg deposition is being studied. To assist in such experiments, a highly sensitive force transducer has been constructed to measure contractions of the common oviduct of the female moth.

Cotton leafperforator and Lygus populations in four 40-acre fields were lower throughout the season in nectariless cotton than in normal nectaried cotton. Pink bollworm populations were extremely low in fields of both cotton types. Chemical termination of cotton fruiting with plant growth regulators continues to show promise as a means of reducing populations of diapause pink bollworms. Aerial applications of MCPA (0.025 lb/ac) + chlorflurenol (0.5 lb/ac) to four growers' fields reduced the number of green bolls by an average of 64% (56%-80%) with little or no reduction in yield. Diapause pink bollworm larvae were found in only one grower's field. In this field they were reduced 60% by the chemical termination treatment. The number of larvae in the terminated nectariless plots were reduced 85% compared to non-terminated nectaried cotton. Small plot tests showed that Pennwalt TD-1123 (3,4 Dichloroisothiazole 5-Carboxylic acid) was superior to 2,4-D or MCPA in combination with chlorflurenol or CCC.

Overwintered pink bollworm moths that emerged >21 days before blooming usually failed to produce any progeny in cage tests due to absence of suitable larval food. However, abnormally cool temperatures in 1975 resulted in some reproduction by overwintered moths that emerged 26 days prior to blooming. Reproduction was <1 progeny/female. Moths that emerged after blooming had a 3- to 10-fold increase. Moths that emerged prior to or during periods of high temperatures (41°C or more) for four days or more had a greatly reduced reproduction rate.

Tobacco budworm larval and pupal development in relation to temperature was studied, as well as adult survival, egg laying and egg hatchability. Development rates at high fluctuating temperatures, the effect of temperature and humidity on diapause and estivation initiation were determined. Similar information for bollworms was used to develop two models useful for predicting the development of bollworms in sweet corn in Idaho. Another model has evaluated the chemical control of beet armyworms in chrysanthemum ranges in Florida.

No dark cabbage loopers were recovered during the spring and summer of 1975 after large releases of dark cabbage loopers in the fall of 1974.

#### Tucson, Arizona

Five diets were tested for *Lygus* bugs: (1) green beans, (2) lettuce, (3) green beans + heat-killed beet armyworms, (4) lettuce + heat-killed beet armyworms, and (5) heat-killed beet armyworms. Green beans were better than lettuce for both survival and developmental time and added beet armyworms improved both the plant diets. Nymphs fed on beet armyworms alone developed faster than on other diets, but survival was reduced. The best diet in regard to survival and developmental time was green beans plus beet armyworms.

Beet armyworms preferred to pupate in cloddy, dry to wet soil, and, generally, attached pupal cells to the sides of the clods. Soil temperatures above 38°C were avoided. Adult emergence from buried pupae was limited if pupae were buried deeper than 4 inches. Near total mortality of beet armyworms occurred from pressures greater than 0.4 lb/inch<sup>2</sup> applied to naked pupae. Total mortality did not occur when 1.5 psi was applied to the beet armyworm pupae in earthen cells. Appreciable mortality occurs due to summer cultivation of cotton.

The tachinid, *Exorista mella*, was released against the range caterpillar, *Hemileuca oliviae*, in northern Lincoln County, New Mexico. Adults reared from subsequent collections of the range caterpillar appeared to be the same species, or a closely related species.

A tachinid, *Palexorista laxa* (Curran), imported from India, was successfully reared in the laboratory at temperatures from 59° to 90°F, but survival was low at the extremes. At the optimum temperature, each female produced 62-70 progeny. Fewer labor-consuming techniques were developed for the native Ichneumonid parasite, *Microplitis croceipes*, but a low return resulted.



Studies of the pupation sites of Heliothis zea and H. virescens indicated the prepupae pupated in soil of any texture, had a slight preference for moist soils, but avoided sites with temperatures greater than 38°C. When pupae were buried 1-6 inches, the moths emerged in declining numbers as the burial was deeper and more moths were deformed. Emergence from pupae buried in cells was better than from naked pupae. Irrigation of the soil sealed the emerging moths in the tunnels. Pressures in excess of 0.4 lb/inch<sup>2</sup> generally killed the pupae, indicating that summer cultivation results in severe mortality.

Developmental rates and adult longevity and fecundity were determined for Bracon gelechiae Ashmead and B. greeni Ashmead. Both are difficult to rear on pink bollworms, and no recovery of the parasites was made from a small plot of cotton infested with pink bollworms. Parasierola emigrata Rohwer is moderately good at finding and parasitizing pink bollworms that make cells in trash prior to pupation or diapause, but larvae in cells in the soil are nearly free from parasitism. Larvae in cells in open bolls were also parasitized. Chelonus curvimaculatus was obtained from Ethiopia and research was initiated to evaluate the parasites for pink bollworm control. Apanteles sp., a larval parasite, was obtained from Australia but was not cultured because it failed to mate in the laboratory. Studies of the pupation sites of pink bollworms indicated that the prepupae tend to pupate in shaded, damp, loose, slightly lumpy soils in which some trash has accumulated. These ideal conditions exist in the part of the row directly beneath the plant and become more favorable as the plant canopy closes, soil temperatures decrease, cultivation ceases, and more trash accumulates. Pressures exerted by cultivation equipment are adequate to kill from 10 to 85 percent of pink bollworms pupating in vulnerable parts of the cotton row. Studies of cultural control of the pink bollworm indicate that early crop residue destruction, deep plowing, and subsequent water seal result in lower overwintering pink bollworm population, that fail to develop to damaging levels in most years. In the study area, six sprays were applied for pink bollworm control in 1971 and 1972 before the controls were initiated. In 1973, three sprays were necessary in early September for boll protection. An intensified program in 1973 and 1974 resulted in no sprays in 1974 and one in 1975. The soil seal by winter rains or pre-crop irrigations is the critical factor in the control of the overwintering pink bollworms.

#### Stoneville, Mississippi

For the first time since light traps have been used as Heliothis spp. survey tools at this laboratory more Heliothis virescens than H. zea moths were collected in the 1975 growing season. Growers experienced more difficulty in controlling H. virescens especially in the North Delta than in previous years.

Results of a survey to determine the seasonal association between predators of Heliothis spp. and other beneficial arthropods and habitats (land use) in Washington County, Mississippi, showed that higher overwintering populations of beneficial insects occurred in the marginal than in the more homogeneous areas. The marginal areas probably play a major role in the winter survival, spring population buildup and population of beneficial arthropods in this



agroecosystem. Heliothis spp. populations were found to be 5 times greater in cotton than in soybeans. Populations were higher and fluctuated more in cotton than in soybeans.

In baited sticky traps plastic Hercon strips impregnated with virescence when changed biweekly were as effective in capturing males as 3 virgin female H. virescens per trap changed 3 times per week.

In field plot tests against moderate Heliothis spp. infestations, 3 synthetic pyrethroids (FMC 33297, SD 43775 and SD 41706) and 2 organophosphorous compounds (BAY NTN 9306 and CGA 15324) gave good control and significant increases in yield over check. A nuclear polyhedrosis virus and a mixture of Bacillus thuringiensis and chlordimeform gave fair-to-good control of Heliothis spp. with increases in yield over untreated check. Conidia or Normurea rileyi were produced in the laboratory at about 60 grams by dry weight every 21 days for laboratory and field testing against Heliothis spp. on cotton and corn. In a preliminary field test N. rileyi was not effective against Heliothis spp. at the dosage used.

No significant differences among treatments were found in numbers of thrips, numbers of tarnished plant bugs or yields in small-plot test comparing in-furrow at planting granular formulations of DS-15674 at 0.3, 0.6 and 1.0 pound, disulfoton and aldicarb each at 1.0 pound, Nemacur at 1.62 pound per acre and untreated check.

In a replicated field test tarnished plant bugs caused more than 50 percent terminal abortions in 5 cotton varieties. Differences in plant bug numbers among varieties in plots interplanted with mustard were small but D&PL-16 and Stoneville 213 showed more tolerance yielding 1850 and 1640 pounds of seed cotton per acre, respectively, compared with 849, 599 and 415 pounds for Coker 201, La 17801 and ORS-73C, respectively.

Two parasites, a dipteran and a parasitic wasp larva (both undetermined species) were found in tarnished plant bug populations collected from fleabane. The highest parasitization rate, 61%, occurred on June 30.

Results of greenhouse tests showed that the tarnished plant bug can cause damage to the cotton plant in the presquare stage often called "crazy cotton." Cotton plants in the cotyledon, 2nd-, 4th- and 6th-node stages were exposed to one plant bug per plant for 72 hours. Percentages of damaged plants were 72, 94, 72 and 67, respectively.

Spider mite infestations were held in check by frequent rains and an Entomophthora spp. fungus which was present in all populations. In laboratory tests Fisons NC 13292, Zoecon ZR 856, Zoecon 1713 and Chemagro BAYBUE 1452 compared favorably with dicofol against spider mites.

A native predaceous mite, Neosilus fallacis, at rates of 22,000 and 110,000 per acre was introduced in 2 cages containing cotton plants infested with the 2-spotted spider mite Tetranychus urticae on July 29. Data indicated considerable initial reductions in the phytophagous mite populations. However, populations also decreased to a low level in the check cages by September 10.

Thirty-six boll weevils were collected in in-field pheromone-baited traps in a cotton field on the Delta Branch Experiment Station before plants produced oviposition-size squares. The infestation in the field was very light for the remainder of the season indicating that the in-field traps would be effective in preventing injurious late-season infestations if overwintering weevil populations were low.

Boll weevils were collected each month, except December, in pheromone-baited Leggett traps installed around a cotton field on the Grissom farm near Stoneville. The greatest number was collected in May. The total of 293 compares with a total of 2941 collected in the traps at the same location in 1974. In a similar test in a field on the Delta Branch Station, 444 boll weevils were collected in the traps. In 1974, 730 were collected at this location. Hercon strips impregnated with grandlure showed promise as baits for traps used to collect or capture boll weevils.

Four cotton fields, approximately 40 acres in size, in different locations were studied in 1975 to relate Heliothis spp. problems to certain agricultural practices and to correlate beneficial arthropod populations with field types. Data profiles were constructed for each field which included all agricultural practices, entomological data and plant-growth information. All insect sampling with a D-Vac machine was done by random design and arthropods were counted and identified in the laboratory under magnification. Cotton pest populations were sampled by additional plant examinations in each plot. Plant growth was monitored by measuring plant height and counting squares, blooms and bolls on a row basis each week.

A Heliothis spp. infestation developed in mid-August in the cotton field with the highest fertilizer rate (100 lb-N/acre) but the maximum boll damage recorded was only 8%. The field which received no fertilizer in 1975 had no Heliothis infestation during the entire season. Predatory arthropod populations were highest in the unfertilized field which also was the only field planted with untreated seed. Population curves for the season showed that predator numbers were reduced after insecticides were applied for control of plant bugs, Lygus spp., or Heliothis spp. Leafhopper populations were much higher than plant bug populations in 3 of the study fields. The leafhopper populations peaked at well over 100,000 per acre. No single predator species or group was outstanding in any field. The most common early season predator was Orius insidiosus. Chrysopa spp. increased late in the season. Among lady beetles Colemegilla maculata was more common than Hippodamia convergens. Neither Georcoris spp. nor Nabis spp. were common in the fields. The Lynx spider Oxyopidae spp. was the most common spider with 75% of the spider collections consisting of this species. Predator populations in late-planted cotton (early June) never became high enough to be of significant value in controlling Heliothis spp.

#### Tobacco Insects

Technological Objective: New and improved methods to reduce losses caused by insects attacking cotton.



## Oxford, North Carolina

Evaluation of the contact toxicity of insecticides used on tobacco against beneficial insects was completed. Monocrotophos, azinphosmethyl, methidathion, parathion and malathion were the most toxic to the hymenopterous parasites with acephate, carbaryl and trichorfon the least. Methomyl, methidathion, monocrotophos and encapsulated methyl parathion were the most toxic to the spined stilt bug. Residues of azodrin on potted tobacco plants remained toxic to stilt bugs for 60 days after application compared to only 24 days for methomyl.

Parasitism of adult tobacco flea beetles by Howardula nematodes ranged from 1-20% at Oxford and 0-30% at Clayton in 1975. Parasitism of flea beetle larvae ranged from 0-80% at Oxford and 0-60% at Clayton. Direct mortality of tobacco flea beetle larvae from Howardula parasitism was verified. Death eventually resulted from the release of juveniles into the body cavity by parasitic females. This occurred in about 70% of the parasitized larvae collected in 1975. A taxonomic description of this Howardula nematode has been prepared.

Eight of 9 economic species of Chrysomelidae were found to be parasitized by Howardula nematodes. New species of Howardula were found in Chaetocnema flea beetles and the grape colaspis.

Our tobacco plant bed study continued to indicate that recommended early destruction after transplanting may be detrimental rather than helpful in suppressing tobacco budworm populations. Plant beds act as a trap crop with heavy infestations occurring while only light infestations are present in the smaller transplanted tobacco. Over 60% of the larvae are parasitized; less than 20% pupate and the remainder die from miscellaneous causes.

To augment early season populations of an important hornworm and budworm egg predator, the spined stilt bug, this insect was reared on tobacco in cold frames in a field later to be transplanted to tobacco. After transplanting the cold frames were removed to allow dispersal. Half of 16 test plots were seeded with non-viable hornworm eggs to provide food for the stilt bugs but only 6 of the 8 plots seeded showed increases, up to 3.5-fold, in stilt bug populations and 5 of the 8 unseeded plots had increases up to 6-fold.

Tachinid parasites did not appear on the tobacco budworm until late in the season when Campoletis sonorensis and Cardiochiles nigriceps had become scarce (6.9% of 233 larvae parasitized). Larvae with Tachinid eggs totaled only 32 (13.7%) and only 6 of these (2.6%) produced parasites, primarily Winthemia rufopicta. Only 7 (2.9%) of these collections were the corn earworm.

Because of the difficulty in procuring CSM (cornmeal, soy flour and powdered milk) the main component in our insect diets, CS (65% cornmeal and 35% soy flour) was successfully substituted in a universal diet for rearing laboratory colonies of the tobacco hornworm, the tomato hornworm, the tobacco budworm, and the corn earworm and for field collections of these and other lepidopteran species found on tobacco.



In our large area study involving weekly surveys of 40 or more fields, no economic thresholds (insect infestation levels justifying treatment) were observed from 1967 through 1972, however, from 1973 through 1975 the number of economic thresholds per field increased to 0.25. Various factors are being studied to determine the causes of these increases.

In cooperative tests with the Brownsville, Texas, laboratory the new sex pheromone, virelure, for the tobacco budworm was evaluated in electric grid traps. One virelure trap caught 1547 males during the entire season while a trap with 20 virgin females at the same location caught 4578 males. At separate locations (3) virelure traps averaged 1411 males; a single blacklight trap (BL) caught only 44 and BL plus Virelure caught only 164 males. We now have a feasible method for measuring adult tobacco budworm populations and we will routinely operate 12 of the virelure-grid traps in our large 1250 mile<sup>2</sup> study area.

In cooperative studies with the Gainesville, Florida, laboratory 2 sex pheromones have been identified for the tobacco hornworm and extracts of the corn earworm pheromone have been isolated.

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Cotton Insects

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NRP Annual Report  
FY 1976

NRP 20240 Insect Control, Grains, Forages, Sugar Crops and Oilseeds

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Technological Objectives

1 Reduce crop losses in field crops by conducting research to control insects and mites.

(Sub-technological objectives included under each subprogram)

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The purpose of this NRP is to develop control strategies to protect field crops from insects and mites and contributes directly to program 677, Crop Production Efficiency Research, Operating Goal 2, New Knowledge to Increase Productivity and USDA Mission 2, Agriculture Production Efficiency.

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Selected Examples of Progress

T01.1. Reduce crop losses in corn by controlling or suppressing insect and mite populations.

Plant Resistance

Corn composites, synthetic varieties, exotic germplasm and corn belt inbreds (ca. 10,000 plots) were evaluated for first-brood European corn borer resistance. First- and second-brood resistance was combined into one genotype. Progress was made in selecting for both first- and second-brood resistance in a 10-line synthetic variety of corn. (Ankeny, IA)

Of 77 corn genotypes evaluated in late planted field tests for fall armyworm resistance, 2 recurrent populations, 7 inbred and 5 single cross lines with MP 496 parentage were found to be moderately resistant. (Stoneville, MS)

Hybrids tested in the field did not vary significantly in their reaction to silk feeding by adult western and northern corn worms. (Brookings, SD)

Field measurements on the number of corn earworm larvae recovered from silks of selected crosses indicate that selection progress for that character is possible.  $S_1$  progenies within several populations were evaluated for corn earworm injury. Each will be recombined and advanced to the next cycle of selection. Fifty recently received selections of corn from Mexico and South America were screened for corn earworm injury. Some resistance was found. A convergent improvement study was used to



incorporate 7 chemical and physical plant resistance characters into 1 corn population. Both selections within the ZC-2451 X 81-1 cross have produced up to 50% dead earworm larvae on ear silks in 3 days. Twenty seven commercial short season hybrids were screened for insect resistance. One of these was rated very good to overall insect resistance. Several experimental inbreds selected from highly earworm resistant cross of the white 471-U6 X 81-1 are near release. (Tifton, GA)

The population of corn developed for resistance to first-brood southwestern corn borer by recurrent selection technique exhibited 50% less larval survival, significantly smaller larvae, increased larval development time, and significantly less leaf feeding damage and stalk tunneling than susceptible corn. A method for infesting corn to determine resistance to maize weevil was developed. (Mississippi State, MS)

### Biological Control

In experiments with Trichogramma, it was found that extracts of moth scales or the appropriate synthetic kairomone applied to plants in early season or at other times when the natural infestations are not high, significantly increase the rate of parasitization by Trichogramma. It was also found that continuous exposure of Trichogramma females to substrates treated with kairomones increases the rates of parasitization, increases longevity, and the total progeny produced by each female. (Tifton, GA)

In studying the effects of Nosema pyrausta on the European corn borer, it was found that Nosema did not decrease the interplant migration of the borer, but the number of larvae per plant was affected inversely by the amounts of N. pyrausta used to artificially infest the maize plants. Also, N. pyrausta infected 65 and 95% of the corn borer population when applied to the corn plants during the first- and second-generation periods, respectively. (Ankeny, IA)

The tachinid parasite, Lixophaga diatraeae, was demonstrated to complete development in all stages of the southwestern corn borer in the laboratory. However, it was concluded that the parasite would not be effective in controlling the southwestern corn borer because the early instars are hidden behind leaf sheaths and do not produce the large amount of frass necessary for host seeking and larvapoosition of these parasite flies. (Stoneville, MS)

Apanteles militaris (Walsh), a braconid parasitoid, was found to attack third, fourth, and fifth instar larvae of Pseudaletia unipuncta in the laboratory, and the parasitoids from the laboratory colony successfully parasitized hosts in field cages. (Brookings, SD)

## Chemical Control

Sevin resistance, both chemical and behavioral, was shown in the fall armyworm with resistance occurring in all areas of the southeastern States sampled. An increased tolerance to methomyl has been shown in the fall armyworm in southern Florida. A procedure was developed for insect and plant disease control consisting of an application of carbofuran followed by foliar applications of either monocrotophos or methomyl along with mancozeb as needed to allow double cropping of corn in south Georgia. (Tifton, GA)

Soil applications of carbofuran at lay-by time were found effective in controlling second generation European corn borers. Spray applications of synthetic pyrethroids were effective in controlling European corn borers and corn earworms on sweet corn. (Ankeny, IA)

In-furrow applications of systemic insecticides at planting were found to be ineffective in controlling fall armyworm populations in late planted silage corn. Methomyl rates of 0.25 and 0.33 pounds ai/a gave as good a control as rates of 0.5 and 1 pound ai/a during the same time period. (Stoneville, MS)

Baseline responses were established to determine the relationships of LD 50 and LD 90 values of larvae in adults of southern, western, and northern corn rootworms. These data indicate that each compound responds differently to either larvae or adults among rootworm species. Studies show that third instar western corn rootworm larvae have higher cholinesterase levels than western adults and either larvae or adults of the southern corn rootworm. (Brookings, SD)

## Insect Rearing

A new diet based on cheap, readily available materials such as corn meal, soyflour, and milk substitutes compared favorably with standard diets for rearing the corn earworm. Through cooperative efforts with agricultural engineers achievements were made in the mechanization of rearing the boll weevil, Anthonomus grandis. This process is carried out in a continuous operation on an inline form-fill-seal machine. Efforts are underway to demonstrate the capability of the technique and equipment to rear 5 million weevils per week. (Tifton, GA)

A new rearing facility was renovated and equipped during the spring of 1976 for production of southwestern corn borer. (Mississippi State, MS)

Insects (Heliothis zea) reared on casein, soyflour, or cottonseed meal diets, were of comparable quality, but those reared on cottonseed, flour or corn-germ flour diets were inferior in many categories. In rearing corn earworms over 5 successive generations, soyflour-wheat germ diets that contained cottonwood sawdust or corncob grits and a reduced amount of agar were superior to diets containing oak sawdust and equal

or superior to diets that contain the "full" amount of agar. Corn earworms develop better on flash-sterilized diet than those developed on the standard (nonsterile) diet. (Stoneville, MS)

Large numbers of western corn rootworm larvae were reared to the third instar using germinated corn on germination paper that was connected by a wick to a water reservoir. This method provides easy access to the third instar larvae and a relatively stable environment with minimum maintenance and facilities. (Brookings, SD)

#### Sex Pheromones

Gas and high pressure liquid chromatographic systems were developed which allow isolation and identification of nanogram quantities of pheromonal chemicals from the European corn borer. Four C14 acetate esters from extracts of the female European corn borer ovipositor were identified. The complete behavioral significance of this set of compounds has not been determined. However, preliminary male sex stimulation assays have shown that one of the compounds can suppress male sex stimulation responses. (Ankeny, IA)

Two aldehydes have been isolated from female southwestern corn borers and identified as Z-9-Hexadecanal and Z-11-Octadecanal that elicit a strong laboratory response from males. The two compounds have been synthesized and bioassayed. They give the same male response as a natural component. (Mississippi State, MS)

Females of the western corn rootworm are found to release a pheromone that was attractive to males of both western and northern corn rootworm under field conditions. A non-destructive method for collection of the pheromone and a laboratory bioassay were developed. The pheromone has been partially purified and some work on identification done. (Brookings, SD)

#### Insects as Vectors of Plant Pathogens

In field trials, Graminella nigrifrons developed on barnyard grass, crabgrass, Bermuda grass, and ryegrass throughout the seasons. Populations were less on Johnsongrass and nil on corn. G. nigrifrons were found to overwinter in the egg stage at Wooster, Ohio. In field plots in southern Ohio MCD was 5 times more prevalent than MDM (31.6% vs 6%). Of 43 inbreds rated for virus infections, 14 inbreds were resistant to MDM and 2 inbreds were resistant to both MDM and MCD. (Wooster, OH)

T0.1.2. Reduce crop losses in small grains and rice by controlling or suppressing insect and mite populations.

#### Host Plant Resistance

Wheat, barley, and triticale entries (16,476) were evaluated for resistance to biotypes of Hessian flies. More than 2,500 entries were evaluated for cereal leaf beetle resistance. Downy, a soft red winter wheat



variety, resistant to the cereal leaf beetle and all biotypes of the Hessian fly, and Key of high protein and H<sub>6</sub> Hessian fly resistance, were released by Purdue and USDA. Ruler, a Hessian fly resistant wheat having the H<sub>3</sub> gene for resistance, was released by the Ohio Agricultural Research and Development Center. Data from field releases of the Great Plains biotype show that after 4 field releases the native population was suppressed from 250,000 to 2,000 per acre, whereas the control population of native flies increased almost 2-fold. Studies show Knox 62 and Purdue 4835 do not differ from one another genetically for Hessian fly resistance. Both appear to have the H<sub>6</sub> gene and differ from Arthur with the H<sub>3</sub> gene by a single dominant gene. A continuing program of breeding and screening for cold tolerant winter barley lines for cereal leaf beetle resistance was conducted. Two sources are resistant, CI 6671 and CI 6569, and have been incorporated into Paoli and Harrison type spring barleys. Leaf pubescent from Avena sterilis is being tested for cereal leaf beetle resistance but the level of resistance obtained to date is not as good as is available in wheat. (West Lafayette, IN)

Approximately 5,000 wheat breeding lines and crosses from the Missouri, Kansas, and Nebraska programs were screened for resistance to Hessian fly biotypes. Five hundred advanced breeding lines were screened for high levels of resistance and resistant plants returned to the plant breeders for further testing. (Manhattan, KS)

From 750 rice lines screened, 30 lines were selected for further study of antibiosis to rice water weevil larvae; 97 displayed possible tolerance. Approximately 75% of the F<sub>2</sub> progeny from 1974 crosses of tolerant lines PI 162162 and PI 162254 displayed good root regeneration under heavy larval pressure. Twenty three of 99 F<sub>3</sub> test lines from a WC 1541 Gulf Rose cross were highly resistant to the rice stalk borer. Eighteen of 100 lines screened for rice stink bug were selected for further testing (Baton Rouge, LA)

Testing of entries of wheat, barley, oats, and related species from the World Collection and segregating populations of wheat and barley for cereal leaf beetle resistance has been continued. Eight lines of hard red winter wheat and the bulk of these lines plus 16 sibs of these lines and 10 lines from other crosses have been assigned CI numbers and entered in the World Collection of cereal leaf beetle resistant germplasm and are being released. Fifty lines of resistant hard red spring wheat for three back cross populations of Fletcher, ERA, and Waldron by CI 9321 have been selected and reselected in 2 years of field testing. (East Lansing, MI)

With regard to host plant response of Lysiphlebus testaceipes, a Braconid parasitoid of greenbugs, greenbug plant resistance was not detrimental to the parasite and response of the parasitoid may be enhanced by plant resistance in some cases. (Stillwater, OK)

### Biological Control

Convergent lady beetle adults were obtained from hibernation, released in fields, and studied for behavioral characteristics for biocontrol. Attempts at keeping released beetles in the field by providing shelter, offering water, and releasing at night were generally unsuccessful. Lysiphlebus testaceipes was reared on greenbugs on plants, and air-shipped as mummies to Texas for early release.

### Genetic and Behavioral Control

The dark mutant trait of the cereal leaf beetle has been incorporated into the nondiapause culture which is in its 26th generation. No differences in storage of normal or dark strains under the chi-square analysis was found and no difference in food consumed, either total or daily feeding values between black and normal beetles of the same sex when dark and nondiapause cultures were compared. (East Lansing, MI)

### Chemical Control

Mesurool seed treatments at rates as low as 0.2 pounds ai/cwt controlled rice water weevil larvae but phytotoxicity and interaction with propanil reduced seedling stand and the treatment caused yield loss. Bayer 92114, as a seed dressing, provided good control with no seedling detriment at rates up to 1 pound ai/cwt. Sodium azide provided control of rice water weevil larvae at the rate of 5 pounds ai/a applied 10 days post flood. (Baton Rouge, LA)

Field collected greenbugs from Texas, Oklahoma, and South Dakota were not satisfactorily controlled in the greenhouse with tests by maximum allowable insecticide rates. Resistance to disulfoton was calculated to be 30-fold; however, other insecticides, most of which were not yet cleared for use, showed little or no loss of effectiveness. (Stillwater, OK)

### Economic Threshold and Losses

Four years of data have shown no consistent trends of losses in wheats to varying intensities of Hessian fly populations; however, a significant regression of yield on the number of puparia showed that the weight of wheat heads decreased in proportion to the number of puparia per culm. (West Lafayette, IN)

In caged Larker barley studies, 21 cereal leaf beetle eggs and 3 larvae per 20 stems of 5th blade and 11 larvae per 20 stems of late boot stage plants reduced grain yields from 52.9 grams per meter foot of row on non-infested plants to 26.3 grams on infested plants. (East Lansing, MI)

### Insect Vectors and Transmissions of Virus and Pathogens

When virus specific antiserum was injected into the hemocoel of aphids before they acquired barley yellow dwarf virus by feeding on infected

leaves, transmission of the virus was consistently either reduced or prevented by the homologous antiserum when compared with the control serum. The procedure was useful for studying both the transmission of the RPV isolate of barley yellow dwarf virus by Rhopalosiphum padi and the transmission of the MAV isolate by Macrosiphum avenae. Tests with injected R. padi provided additional support for the role of Genomic masking in the dependent transmission of the MAV isolate by R. padi from mixed infections of RPV and MAV. Other tests indicated that dependent transmission of MAV by R. padi was not restricted to the 2 virus isolates under study, but also occurred for range of isolates similar to RPV and MAV. This finding supports a possible role of dependent transmission in the field. (Ithaca, NY)

T01.3. Reduce crop losses in grain sorghum and millets by controlling or suppressing insect and mite populations.

#### Host Plant Resistance

Eighty seven new sorghums were screened for sorghum midge resistance. Lines 1209 CM, 1217 CM, 1731 CM, 17949 CM, and E-248-A were the least damaged sorghum. Numerous sorghums were evaluated for midge resistance in cooperation with personnel of Texas A&M at Lubbock and Purdue University. Georgia grain sorghum trials were evaluated against the complex of sorghum insects. All varieties were fairly susceptible. (Tifton, GA)

Over 4,300 sorghum lines and  $S_1$  progenies were screened in the greenhouse for resistance to the greenbug. Two populations and 29 lines with resistance to greenbugs were released in FY 1976. (Lincoln, NB)

Resistance to shootfly was still being maintained in  $F_{3's}$  of resistant X High Yielding lines. Leaf feeding and stem tunneling by the stem borer was not always correlated, but artificial infestation showed resistance is sufficiently effective to give good yield under moderate infestation levels. Some sorghum varieties are relatively less damaged by both the stem borer and the shootfly. (Stillwater, OK)

The shootfly resistant IS lines have been crossed with high yielding lines. Lines with Indian cytoplasm had more tolerance than those with zafer, milo, or Fetarita cytoplasm. (Parchani, India)

In investigations on the effect of fertilization on the expression of host plant resistance in millets it was found that any change in fertility of growth media affecting the nutritional quality of the host plant changes the expression of host plant resistance in millet cultivars. Also, larval mortalities increase from high to low rates of fertilization. (Tifton, GA)

T01.4. Reduce crop losses in grasses and legumes by controlling or suppressing insect and mite populations.

#### Host Plant Resistance

Approximately 1,300 plants were selected for resistance to biotype H of the spotted alfalfa aphid and released to alfalfa breeders in



Arizona, Nevada, North Carolina, and Florida for development of multiple pest resistance. Over 180 selections with pea aphid resistance were released to breeders in Arizona and Nevada. Progenies of 9 new experimental alfalfas developed for multiple pest resistance were evaluated for resistance to the spotted alfalfa aphid, pea aphid, and the blue alfalfa aphid. Resistance to 2 aphid species was demonstrated in 1 USDA-Arizona experimental (ARS-PA). (Tucson, AZ).

Fifty-five accessions of Hemarthria altissima and 2 accessions of H. uncinata were screened in the laboratory. Nine accessions had significantly fewer aphids than the susceptible control pangolagrass. Four accessions of H. altissima demonstrated a high level of resistance, comparable to that previously found in Digitaria sp. Studies with selected Digitaria accessions demonstrated that a high level of antibiosis contributed to resistance in this material. Thirty two Medicago sp. comprised of 419 accessions were evaluated in the laboratory for resistance to alfalfa weevil larvae. A high level of antibiosis was demonstrated in several accessions of 2 species of M. scutellata and M. rugosa. The resistance is attributed to the glandular tipped hairs located along the stems and pedioles of these species. (Beltsville, MD) Seventeen cultivars of Kentucky blue grass were field evaluated for resistance to the blue grass billbug. Some cultivars were more resistant to billbug infestations and permanent damage than others. Twenty nine grass cultivars were evaluated for resistance to the greenbug. Thirteen cultivars were immune to greenbugs. (Lincoln, NB)

### Biological Control

During recent studies involving mass production of spores of N. locustae for field tests, production per grasshopper varied between  $1.0 \times 10^9$  to  $8.0 \times 10^9$  per grasshopper. This is sufficient inoculum to treat from 1 to 8 acres. The temporary exemption from tolerance, temporary labels, and an experimental use permit for Nosema locustae were approved by EPA. This is the first instance of such clearances and approvals for the use of a protozoan pathogen for control of a noxious insect. Subsequent sampling at 4-9 weeks after treatment established that between 15-70% of the grasshoppers on the treated plots were infected as a direct result of the applications. (Bozeman, MT)

Some bird species were found to be very effective in controlling adult billbugs. (Populations of 16 adults per square foot were reduced to less than 1 adult per square foot within 4 days.) (Lincoln, NB)

### Chemical Control

Systemic insecticides Carbofuran, Thimet G and Disyston G were soil incorporated during spring planting of alfalfa. Results demonstrated for the third year that systemic insecticides protect spring seeded alfalfa from potato leafhopper. In studies involving candidate materials for the control of alfalfa weevil larvae, Ciba-Geigy CGA 12223 and CGA 15324 were found to have activity similar to the standard carbofuran. Compounds demonstrating moderate activity were Union Carbide UC 51717, UC 51109, and Mobil Oil MC 9087. Small plot tests with 7 chemicals

submitted by 5 commercial cooperators were made to determine the efficacy for potato leafhopper control. Activity was compared with the standards methoxychlor, dimethoate, and carbofuran. FMC Corporation's synthetic pyrethroid FMC 33297 and Ciba-Geigy CGA 15324 were as active as methoxychlor. Union Carbide UC 51109 and Mobil Oil Company MC 9087 were comparable to dimethoate and carbofuran. (Beltsville, MD)

In laboratory bioassays, 9 topick and 12 oral administrations of 13 candidate insecticides were tested against grasshoppers. FMC 27289, FMC 35001, and SD 41706 were more than 10 times as toxic as the standard treatment with technical malathion. Also, a 0.3% bait formulation of carbaryl on wheat bran produced symptoms of poisoning within 30 minutes after ingestion and a 1-hour feeding exposure caused 85 to 95% mortality after 72 hours. In field tests applied by aircraft, 8 and 4 ounces of actual insecticide per acre of undiluted Pencap M, a microencapsulated formulation of methyl parathion gave as good control of grasshoppers as the standard ULV application of 8 fluid ounces of malathion. (Bozeman, MT)

Eight insecticides were evaluated for adult control of billbugs. Mocap at 5.2 pounds ai/a was effective at Lincoln, NB. Carbofuran granules applied to alfalfa in a spray at 1 pound ai/a reduced clover root curculio larvae, Sitona hispidulus (F.), for the fourth year in a row. Roots of treated plants were larger and had less injury than untreated plants. However, the stand declined regardless of insect control. (University Park, PA)

### Cultural Control

Spring grazing reduced populations of the black grassbug by 70% for the second consecutive year. (Corvallis, OR)

### Economic Thresholds and Damage Levels

"Silver top" (sterile seed heads) was more noticeable than in any previous year, especially in blue grass. Several additional grass genera were heavily infested, especially Calamagrostis seed production plantings where up to 50% of the heads were sterile. (Palmer, AK)

On short grass rangeland that produced 1,750 pounds of forage per acre, grasshoppers that reached a density of over 33 per square yard consumed 2.5 times as much forage as domestic livestock. Data on phenology and biomass of plants and grasshoppers, air and soil temperature, soil moisture, and precipitation, as well as grasshopper density and rates of parasitism, were recorded in order to develop a model for predicting forage losses. Feeding tests to determine the rate of forage consumption have been completed for nymphs and adults of 4 additional species--Melanoplus sanguinipes, M. packardii, M. bivittatus, and Camnula pellucida.

Consumption by adults ranged from 6.8 milligrams per day for male M. bivittatus. (Bozeman, MT)

Treatment of alfalfa fields with dimethoate (0.3 pounds ai/a) to control potato leafhopper increased the dry matter 0.3 - 0.6 tons per acre and protein 2-4%. Plant density averages 2 plants per foot higher in treated portions of the fields. In 17 additional fields where dimethoate was applied to control potato leafhopper populations which ranged from 0.5 to over 30 per sweep at their peak in the study fields, losses in protein occurred whenever mean populations were 0.5 per sweep 2 weeks before harvest. (University Park, PA)

### Biology and Taxonomy

Natural photoperiod played a major role in the incidence of diapause in field populations of the alfalfa seed chalcid, where diapause begins about September 1, was completed December 1, lasted until April 15 when adults began emerging, and ended June 15. The day length for induction ranged from 10½ to 13 hours and for termination 13 to 14½ hours. Bio-morphological evidence was found to suppress taxonomically the leafhopper, Gyponana hasta Delong, as a junior synonym for Gyponana angulata (Spangberg). In the second part of the worldwide revision of the subfamily Coelidiinae, the tribe Thagrini was fully revised and redefined with keys, descriptions and illustrations for 2 genera and 139 species. One genus and 103 species were described as new to science. (Tucson, AZ) In a continuing comparison of the 2 alfalfa weevil strains in Nebraska during 1975, the population in Otoe County (eastern strain) continued to increase over the previous year, while the population in Dawson County (western strain) declined from the previous year. Parasitism by the principal parasite (Bathyplectes curculionis) as averaged over the 1975 season, was equal in the two areas in spite of the fact that the eastern strain has some natural resistance to the parasite. A field study was conducted using labeled adult weevils in an effort to study summer migration of the adults from alfalfa fields and to locate over-summering quarters. Movement of adults from the center of the field was observed by locating labeled weevils with a radiation counter. However, the counter was not successful in locating weevils outside of the fields. Some information on over-summering quarters was obtained by counting weevils in soil and under litter in a shelter belt using a pyrethrin drench method. (Lincoln, NB)

### Rearing

Laboratory methods for rearing nymphal and adult chinch bugs on corn stem sections in pint, quart, and one-half gallon cardboard cartons were developed. Adults survived equally well on 5% sugar water solution and corn stem sections. (Beltsville, MD)



Artificial media was developed that reared 2 native species of Sarcophagid grasshopper parasites, Blaesoxipha kellyi and B. reversa, through 5 and 2 generations, respectively. (Bozeman, MT)

T01.5. Reduce crop losses in sugarbeets by controlling or suppressing insect and mite populations.

#### Host Plant Resistance

Selections of beets for plant resistance to the sugarbeet root maggot were made from 2 broad based lines as the beginning of a recurrent selection program. Evaluation of 70 beet breeding lines showed significant differences for root maggot damage. (Kimberly, ID)

#### Genetic Control

Radiation sterilization studies showed beet armyworms became increasingly resistant to 137 Cs gamma radiation as they developed. Irradiation of either beet armyworm pupae or adults results in sterility that increases with the dose to over 90% at 40 krad. A partially sterilizing dose of 20 krad results in inherited sterility in male  $F_1$  offspring of 95% and in female offspring of 84%. Weekly releases of partially sterile beet armyworms at a 9:1 ratio of sterile to normal in replicated caged alfalfa plots reduced the  $F_2$  population of this pest 59%. When male and female beet armyworms partially sterilized by irradiation of pupae were mated to  $F_1$  offspring from crosses of similarly treated males to normal females,  $P_1$  males X  $F_1$  female crosses and  $F_1$  males X  $P_1$  female crosses reduced egg hatch over that of controls by 97 and 99%, respectively. (Mesa, AZ)

#### Economic Thresholds and Damage

Fifteen fields in southern Idaho containing replicated plots untreated and treated with Temik for sugarbeet root maggot control, were monitored for adult populations, damage, and yield differences. Results showed that 70 or more flies per survey stake resulted in significant yield losses. This occurred in 6 of the 15 fields with an average of 3.8 tons per acre yield increase due to the treatment. In greenhouse studies 1 lygus bug per plant killed all sugarbeet plants in 1-4 leaf stage, and 80% of the plants in the 5-6 leaf stage. In larger cage tests, 1, 2, or 3 adult lygus confined to 1 plant during the growing season reduced yield 1.9, 3.4, and 8.2%, respectively. Chemical control of lygus in small field plots of sugarbeets resulted in a minor nonsignificant yield increase. (Yakima, WA)

#### Biology and Ecology

Past research efforts were on suppression of green peach aphid on peach trees with the assumption that all of the aphids migrated from the orchards. However, it was found that the aphids continued to build up on weeds in some orchards. Orchard grass used as a ground cover will greatly minimize the number of suitable weed hosts of the green peach aphid. (Yakima, WA)

## Rearing

Rearing studies showed that large numbers of beet armyworms can be reared in either paper bags or reusable plastic trays at a savings of labor and funds over previous methods. Two melanistic mutants of the beet armyworm have been isolated: a recessive black pupal mutant and a dominant black adult form. These are useful in identifying released moths and in studies of reproductive physiology and competitiveness. (Mesa, AZ)

T01.6. Reduce crop losses in sugarcane and sweet sorghum by controlling or suppressing insect and mite populations.

Twenty one CP '72 and CP '73 varieties were tested for borer resistance. Five were significantly less susceptible than CP 52-68, and only 1 was significantly more susceptible than CP 52-68. Eighty-seven varieties assigned CP '74 numbers were screened for borer resistance in a replicated (2) test. Nine varieties were significantly less susceptible than CP 52-68 and none was more susceptible than CP 52-68. Thirty five clones (US 1 -- US 35) from the cross NCo 310 X Tainan 2n = 96 were tested and found to be resistant to the sugarcane borer. Unreleased variety CP 70-330 was found to be more resistant than the commercial varieties NCo 310, CP 65-357, and CP 67-412, and also much more tolerant of damage by the sugarcane borer. (Houma, LA)

## Biological Control

Sufficient parasites (Lixophaga diatraeae) were reared and shipped to Florida and Louisiana to conduct a pilot test in cooperation with scientists in those States to evaluate Cuban fly releases to control the sugarcane borer. Releases in Florida were made from July to September at a rate of 100 parasites per acre per week over 1,000 acres. Parasitization by L. diatraeae occurred after 3 weeks and increased for about 10 weeks. The cumulative rate of parasitization by L. diatraeae and 2 other naturally occurring parasites in the release area averaged 20% seasonal, peaking at 60% in September. (Stoneville, MS)

Larvaposition response of Lixophaga diatraeae appears to be primarily contact chemoreception with receptors located in the fly front tarsi. Flies larvaposited on frass from the southwestern corn borer and bollworms fed various plant parts, but not frass from larvae fed on wheat-germ diet. The active substance is a polar compound that moves with the solvent front in a chloroform/methanol 9:1 solvent system in TLC. (Stoneville, MS/Mississippi State, MS)

Thirty eight hundred acres of sugarcane was monitored weekly for a 20-week period for sugarcane borer activity. The number of borer larvae per acre and the percent borer larvae parasitized weekly by Lixophaga diatraeae, which was distributed by air release, and that caused by Agathis sp. and Apanteles flavipes, both of which occur naturally, were recorded. At harvest time borer attacked internodes varied from 1.7% to 11.3% in the area where parasites were released. (Canal Point, FL)

No significant differential predation occurred between sugarcane borer larvae parasitized by the Cuban fly and unparasitized larvae. Supplemental water did not increase the survival of Cuban fly females caged on sugarcane plants in the field, but spraying the cages with a 10% sucrose solution increased survival. Cuban flies survived at temperatures normally occurring in Louisiana sugarcane fields. Cuban fly females reared on sugarcane borer hosts had a slightly lower mortality rate than females reared on wax moths. (Houma, LA)

### Genetic and Behavioral Control

Male sugarcane borers irradiated with 10 krad gamma rays were sexually competitive with unirradiated males, but the  $F_1$  male descendants of irradiated males were noncompetitive with unirradiated males. No difference was found in the radiosensitivity between field-collected and laboratory-reared male sugarcane borers. There was no difference in the fecundity of wild females and laboratory-reared females crossed with wild or laboratory-reared males, but wild males were more fertile than laboratory reared males. Field tests showed no significant difference in the sexual attractiveness of laboratory-reared and wild female sugarcane borer moths. Laboratory tests showed that in multiple matings of the sugarcane borer the first mating is the effective mating and there is little or no sperm displacement from subsequent matings. (Houma, LA)

### Chemical Control

One new experimental insecticide, Sandos 155, in small plot tests reduced damage by the sugarcane borer from 9.0% in the check plots, to 2.3% in plots treated twice with 0.75 ai/a. (Canal Point, FL)

### Cultural Control

Three areas of standing sugarcane infested with white grubs, Bothynus spp., were flooded for from 5 to 8 days without measurable damage to the standing cane. Control of the grubs was excellent, exceeding 95%. (Canal Point, FL)

### Rearing

A mass rearing program was developed for Galleria mellonella and for Lixophaga diatraeae on G. mellonella larvae, including development of host larval mass rearing and harvesting methods, methods for parasitizing host larvae, methods for harvesting parasite puparia, methods for shipping parasite puparia, and methods for holding host moths and collecting moth scales. The role of host diet, host stage, and parasite density on parasite quality was elucidated and necessary adjustments made to increase parasite quality. A formalin disinfectant for parasite maggots was developed that aided disease control. Storage of parasite puparia at low temperatures reduced fly emergence, egg production, and adult longevity, but storage of maggots within host larvae at 7-16° C. had no detrimental effects. (Stoneville, MS)



T01.7. Reduce crop losses in soybeans and peanuts by controlling insect and mite populations.

#### Host Plant Resistance

A peanut cultivar fertilized with 3 levels of complete fertilizer expressed different host plant resistance effects to fall armyworms. Means of host plant resistance responses of 4 successive insect generations showed that with cultivar variety variation, 3 different insect populations may result. Significant variation resulted in length of generations, larval development, root larval mortality, and pupal and moth size. The information gained indicates the potential from manipulation of host plant nutrition and resulting resistance expressions. (Tifton, GA)

Two greenhouse techniques for evaluating soybeans for resistance to Mexican bean beetle were developed. Reciprocal  $F_1$  plants from crosses between resistant and susceptible soybeans exhibited antibiosis to Mexican bean beetle, but not as pronounced as in the resistant parent. Defoliation by Mexican bean beetle larvae reared on  $F_2$  plants indicated that antibiosis of PI 229358 may be inherited as an incompletely dominant factor. Of 90  $F_5$  breeding lines with resistant parentage, 77% rated resistant. Five lines selected with good agronomic characteristics in cages had low damage ratings to loopers and bollworms in greenhouse tests.

#### Economic Thresholds and Damage

Seed damage to Pickett-71 soybeans by Heliothis zea and H. virescens depended on pod thickness. Bollworms damaged about 50 and budworms about 43 seeds each when pods were 1.5 millimeters thick. Damage decreased to 4.5 and 3.5 seeds per larvae for bollworms and budworms, respectively, when pods were 5.3 millimeters thick. (Stoneville, MS)

T01.8. Reduce crop losses in oilseeds other than soybeans and peanuts by controlling or suppressing insect and mite populations.

#### Biology and Ecology

Nocturnal flights of the carrot beetle were found to occur primarily prior to 10:30 p.m. None of the 162 synthetic organic compounds screened showed significant attractancy toward the carrot beetle. The most effective attractant was a hot water extract of sunflower roots. Field development of the carrot beetle required from 87 to 107 days, with adults emerging prior to July 15. (Bushland, TX)

#### Economic Thresholds and Damage

Weekly surveys in a date-of-planting test indicated that major pests of sunflower in the rolling plains of Texas were: 1. carrot beetle,

Bothynum gibbosus, 2. sunflower moth, Homoeosoma ellectellum, 3. Cerambicids, Necas inornata and Ataxia hubbardi. Secondary pests included the moth, Suleima helianthana, sunflower beetle, stem weevils, seed weevils, midges, headclipper, and miscellaneous defoliators. (Bushland, TX)

Economic injury levels from midge, Contarinia texana, larvae attacking guar buds were established. Also, 182 guar plant introductions were screened in the field for resistance to the midge. (Bushland, TX)

#### Insect Vectors of Plant Diseases

There was a significant correlation between Rhizopus headrot and infestations of the larvae of the sunflower moth. (Bushland, TX)

#### Publications and Germplasm Releases

	<u>Publications</u>	<u>Germplasm Releases</u>
Corn Insects	59	3
Grain Insects	33	6
Forage Insects	25	1
Sugarbeet Insects	3	-
Sugarcane Insects	13	-
Soybean and Peanut Insects	7	-
Other Oilseed Insects	5	-
Total	145	10

NRP Annual Report  
FY 1976

NRP 20250 Insect Control--Basic Noncommodity Research

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RESEARCH PROGRESS

Technological Objective Number 1: New and Improved Principles and Practices of Insect Control Based on the Selective Disruption of Their Growth, Development and Reproduction.

Scientists in the Insect Physiology Laboratory have discovered new hormone-related branched-chain diamine compounds which inhibit the development of insect larvae. These scientists have also synthesized a number of new secondary and tertiary amine and amide candidate insecticides which also are potent nematocides. (Beltsville, Maryland)

Scientists of the Biologically Active Natural Products Laboratory have synthesized an insect growth regulator that controls mosquito larvae when applied by aircraft at 0.03 to 0.05 pounds per acre. In these field tests, no deleterious effects were observed on nontarget organisms. Also, this chemical is active against the imported fire ant. (Beltsville, Maryland)

In the related program of the Organic Chemical Synthesis Laboratory, a number of highly active insect growth regulators were synthesized. These model insecticides have aromatic and terpenoid moieties and are highly effective against the yellow mealworm, large milkweed bug, Japanese beetle larvae, coconut rhinoceros beetle larvae, mosquitoes, and the cotton leafworm. A slow-release formulation of one insect growth regulator was prepared for field evaluation against the imported fire ant. (Beltsville, Maryland)

Boll weevils are adversely affected by gamma rays. Studies in the Metabolism and Radiation Research Laboratory have shown the lethal syndrome of irradiated boll weevils has a dose threshold and is influenced by nutrition. These scientists confirmed that this syndrome is strongly affected by the number of bacterial colonies in the weevils alimentary canal at the time of irradiation. Most of the radiation damage occurs when only 2,500 to 3,000 rads are delivered. Survival time and vigor can be improved by placing the weevils on a diet rich in sugars and by rearing them without bacteria. An acute dose of 8,500 rads is sufficient to fully sterilize males. This dose plus exposure to Dimulin<sup>R</sup> fully sterilizes females. The median life span of males treated in this fashion is 12 to 14 days. This treatment reduces mating of males from 10 percent to 40 percent during the first 5 days posttreatment by and 50 percent during the sixth and seventh days. Sperm transfer and mating propensity are decreased when weevils are irradiated at the time of emergence. (Fargo, North Dakota)

Scientists at the Metabolism and Radiation Research Laboratory have devised a rapid cytological method to distinguish between irradiated and unirradiated field-collected screwworm flies. This method will be helpful in determining the ratio of released to native screwworms. Also, these scientists working in cooperation with Dr. Marion Laster, Mississippi Agricultural Experiment Station have found that hybrid females



RESEARCH PROGRESS (continued)

derived from crosses between the tobacco budworm and a related innocuous species produce fully sterile males even after 35 generations of back-crossing to tobacco budworm males. The sterility appears to be caused by an extrachromosomal factor. This work was conducted in support of a proposed field experiment to suppress the tobacco budworm with this mechanism. Physiological studies in the Metabolism and Radiation Research Laboratory on sperm maturation and movement in the Mediterranean flour moth and in the pink bollworm have demonstrated that the number of sperm produced as well as their movement into the seminal vesicles is reduced by rearing under continuous light. (Fargo, North Dakota)

Nuclear divisions in embryos of the large milkweed bug occur without the formation of a spindle fiber apparatus. A hypothesis has been developed by scientists at the Metabolism and Radiation Research Laboratory to account for the orderly segregation of the chromosome. According to this hypothesis, the nuclear envelop controls the distribution of chromosomes by providing chromosome homolog-specific attachment sites. In this way, the two homologs become attached to sites on the nuclear envelop that are roughly opposite each other. Consequently, the chromatin condenses into two equal compact masses on the nuclear envelop and subsequently forms separate nuclei. (Fargo, North Dakota)

Diapausing pupae of the tobacco hornworm were shown by scientists at the Metabolism and Radiation Research Laboratory to secrete three times more cuticular wax than developing pupae. This accentuated wax synthesis occurs in the absence of homonal secretions from the brain. The cuticular wax of the Japanese beetle includes n-alkanes, internally branched monomethylalkanes and dimethylalkanes and 3- and 4- methylalkanes with 20 to 30 carbon atoms. (Fargo, North Dakota)

Indoleamines such as melatonin and serotonin appear to be involved in the regulation of biological rhythms. Further, the indoleamines appear to be affected by nor-epinephrine and other catecholamines. Scientists in the Chemical and Biophysical Control Laboratory have found that the levels of melatonin in caterpillars are affected by nor-epinephrine and light. The levels of catecholamines and indoleamines are also influenced by cyclic nucleotides such as cyclic AMP and cyclic GMP. Cyclic AMP-ase was found to be present in all insect tissues that have been studied and this enzyme is somewhat inhibited by nor-epinephrine. Thus, most of the mechanisms that may be components of the biochemical system which causes physiological rhythms have been identified in insects. (Beltsville, Maryland)

RESEARCH PROGRESS (continued)

An effort is being made to discover nonmutagenic chemicals that prevent reproduction of insects and that can be applied in the field. A series of N-benzoyl-N'phenylurease and their sulfur analogs were synthesized by scientists of the Insect Chemosterilants Laboratory. Sterilizing activity of two of these compounds in the boll weevil, housefly, and stable fly exceeded that of the chitin-synthesis inhibitor, Dimilin. (Beltsville, Maryland)

The Biological Evaluation of Chemicals Laboratory found that two treatments induce high levels of sterility in boll weevils. These involve (a) a 2.5-hour fumigation with hempa and an aziridinyll compound, and (b) immersion for 10 seconds in an acetone solution containing AI3-63223. (Beltsville, Maryland)

Methods to measure the quality of mass-reared tropical fruit flies, screwworm, and tsetse flies were devised by scientists of the Insect Attractants Behavior and Basic Biology Research Laboratory. One of these methods consist of measuring the visual sensitivity of insects. Scientists in this laboratory have perfected a technique for using polymorphic enzyme systems (allozymes) to estimate the genetic variability in wild and laboratory populations of insects. These enzyme systems serve as biological markers in assaying the sexual competitiveness of released insects and in measuring their dispersal. (Gainesville, Florida)

T02 New and Improved Principles and Practices of Insect Control Based on Their Behavior and Ecology.

Nutritionally adequate diet and greatly improved procedures for rearing the gypsy moth have been devised by the ARS gypsy moth rearing and pathology unit. Moths of good physiological quality can now be routinely and reliably reared for less than \$10 per 1,000 individuals. A prototype rearing module for producing 10,000 moths per day is being developed. The approaches used will permit a tenfold expansion of production if needed for virus production or for releases of sterile males. (Otis Air Force Base, Massachusetts)

A formulation of the gypsy moth sex attractant disparlure was developed by the Organic Chemicals Synthesis Laboratory which is not washed from leaf surfaces by heavy rainfall. In light infestations (less than one egg mass per acre) scientists of the Ornamentals Laboratory showed that this formulation inhibited mating by 98 percent. In cooperative studies with Magoya University, Maryland Department of Agriculture, and with the Animal and Plant Health Inspection Service, the +-enantiomer of disparlure was shown to attract up to ten times as many males to traps as racemic disparlure. A gypsy moth tissue culture system was devised by the Insect Pathology Laboratory for producing the nuclear polyhedrosis virus. (Beltsville, Maryland)

RESEARCH PROGRESS (continued)

Controlled release microencapsulated pheromone formulations for codling moth and Oriental fruit moth has been developed for field application by the Organic Chemicals Synthesis Laboratory. These formulations strongly disrupted the mating of these pests in the field. Also, the pheromone of the little housefly was identified and synthesized. (Beltsville, Maryland)

In order to facilitate the development of slow release formulations, equations were developed which indicate the amount of active ingredient needed to provide adequate control for various periods of time. (Yakima, Washington)

A synergist for the sex pheromone of the alfalfa looper was discovered which increases trap catch by one hundredfold. An attractant mixture was also discovered for the celery looper. (Yakima, Washington)

Scientists of the Insect Attractants, Behavior and Basic Biology Laboratory found that the vapor phase of the cabbage looper pheromone emits three maserlike infrared lines. The wave lengths emitted match the wave length criteria for long sensilla trichodea. (Gainesville, Florida)

In order to facilitate the selection of visual attractants, spectral sensitivities were determined for compound eyes of the Caribbean fruit fly, sugarcane root stalk borer, and screwworm. (Gainesville, Florida)

The sex pheromone of the Japanese beetle was isolated, identified, and synthesized. The synthetic pheromone is highly effective in the field in attracting males. When the pheromone is mixed with a food attractant and used to bait traps, both sexes are captured. (Gainesville, Florida)

T03 New and Improved Principles and Practices in Insecticide Use.

Two methods of determining residues of the synthetic pyrethroid, FMC-33297, were developed. Both methods involve the use of electron-capture gas chromatography. One method is designed for routine determination of residues and the second is designed for confirmation of the identity of residues. (Yakima, Washington)

An aerosol formulation of 2 percent d-phenothrin was developed by the Chemical and Biophysical Control Laboratory for eliminating live insects from aircraft in the presence of passengers. This formulation causes no irritation or odor when applied in the presence of passengers. The Sumitomo Chemical Company has registered this formulation with the Environmental Protection Agency. (Beltsville, Maryland)



RESEARCH PROGRESS (continued)

A high-speed liquid chromatographic method was developed by the Analytical Chemistry Laboratory for the analysis of Dimilin in beef, poultry, fat tissue, feces, alfalfa pollen, and honey. When Dimilin is fed to chickens at 10 mg./kg feed for 8 weeks, residues of the pesticide are found in the fat at more than 1 mg./kg. Weekly applications of Dimilin at 1/4 kg. per hectare to alfalfa when in bloom does not result in detectable residues in pollen or honey. (Beltsville, Maryland)

A high-speed liquid chromatographic method was developed for the analysis of resmethrin in honey. The use of resmethrin to kill colonies of bees does not result in any residues in honey. Also, an analytical method for carbaryl residues in chestnuts was developed using high-speed liquid chromatography. (Beltsville, Maryland)

When scientists at the U.S. Livestock Insects Laboratory fed nitrofen to sheep about 25 percent of the pesticide passed through the digestive system unchanged. Nearly one-fourth of the pesticide and its conversion products remained in the tissues at 100 hours after treatment. (Kerrville, Texas)

The synthetic pyrethroid, FMC-33297, when fed to lactating goats is largely excreted through the urin and feces. Less than one percent of the candidate insecticide and its conversion products appears in the milk. (Kerrville, Texas)

The Chemicals Coordination Unit documented 253 agreements between ARS entomologists and industrial research laboratories for the cooperative evaluation of candidate insecticides. Industrial laboratories submitted 66 new candidate insecticides. (Beltsville, Maryland)

Considerable headway was made by the Chemicals Coordination Unit in developing computer-assisted methods for the recognition and/or design of improved insect control chemicals. A total of 17,900 insect control chemicals have been characterized using Wiswesser line notations. These notations can be searched by computer for biologically active substructures. The chemical properties of 1,100 candidate insecticides are now stored in a computer memory. (Beltsville, Maryland)

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CALLAHAN, P. S. The Insect Antenna as a Dielectric Array for Detection of Infrared Radiation from Molecules. First International Conference on Biomedical Transducers. Nov. 3-9, 1975, Paris, France. Presented at the Institute for Applied Zoology, Nov. 11, 1975, Bohn, Germany, and at the Biological Institute on Nov. 14, 1975, in Belgrade, Yugoslavia.



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CALLAHAN, P. S. The Insect Antenna as a Dielectric Array for Detection of Infrared Radiation from Molecules. Joint Meeting of Georgia and South Carolina Entomological Societies, Feb. 17-19, 1976. Savannah, GA. Also presented to the Institute of Mental Health, University of North Carolina Medical School on Feb. 24, 1976. Raleigh, N.C.

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Gypsy Moth Rearing and Pathology Unit  
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None.

Insect Pathology Laboratory  
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NRP Annual Report  
FY 1976

NRP 20260 Biological Agents for Pest Control

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TO 1. New and improved technology for discovery and evaluation of biological agents in foreign countries and introduction for control of insects, weeds, plant pathogens and other pests.

Selected Examples of Progress for FY 1976

The following insects and mites were collected and shipped to U.S. laboratories for study or release against the plants indicated: Musk thistle, Carduus nutans - 3429 Ceuthorrhynchidius horridus adults, 1131 Ceutorhynchus trimaculatus adults, Italian thistle, Carduus pycnocephalus - 5500 Rhinocyllus conicus adults; Spotted knapweed, Centaurea maculosa - 6.5 kg of flower heads containing Urophora affinis larvae and Metzneria paucipunctella larvae; Yellow star thistle Centaurea solstitialis - 750 Urophora sirunaseva adults; Leafy spurge, Euphorbia esula - 150 Chamaesphecia empiformis larvae in roots; Tansy ragwort, Senecio jacobaea - 6500 Hylemya seneciella puparia; Skeletonweed, Chondrilla juncea - shoots with Aceria chondrillae. A rust disease, Puccinia chondrillina, attacking skeletonweed was also sent to the U.S. (Rome, Italy)

Collections of leafminers on alfalfa in France, Germany, and Denmark yielded 15 different species of parasites which were sent to the Newark laboratory. Three species of braconid parasites of lygus bugs were shipped to the U.S. for distribution to cooperating State and Federal research organizations. In addition a new egg parasite of lygus was discovered in France. Through the assistance of the Australian CSIRO in Montpellier, France, egg parasites of Sitona weevils were recovered and sent to the Newark laboratory for distribution and release in the U.S. Several species of predators and parasites of the greenbug collected in France were shipped to Oklahoma and Texas via the Newark laboratory. Parasites of two grain aphids were collected and shipped to California. Grasshopper parasites were collected in Southwestern France for ongoing research at the Bozeman laboratory. (Paris, France)

A system was devised to evaluate the relative effectiveness of candidate arthropods for introduction to control waterhyacinth: the moth Sameodes albiguttalis, and the two weevils, Neochetina bruchi and N. eichhorniae, ranked highest among those that were safe to introduce. The life history, ecology, and host specificity of Sameodes was determined; eggs, larvae, and pupae were shipped to the Gainesville quarantine lab for further testing and release. The effect of nematodes, predators, mites, and pathogens on the



Neochetina weevils was studied. A plant pathogenic rust, Uredo eichhorniae, was found on waterhyacinth and its seasonal abundance was measured. Biological and host specificity tests were conducted to evaluate the Chrysomelid beetle Calligrapha polysspila as a candidate to control Sida spinosa in row crops in the U.S. Both adults and larvae fed on the leaves, adults laid 750 eggs each, the larvae fed for 9 days and then pupated in the soil, and a generation required 50 days. Larvae completed their development only on Sida, Malva, and Sphaeralcea; all larvae died in less than 2 days on cotton. Four species of weevils not known from the U.S. were found attacking Sesbania. A plant pathogenic rust and a virus were collected in Argentina from Morrenia odorata (strangler vine), a weed of citrus orchards. (Hurlingham, Argentina)

During the year, 249 shipments of foreign insects were processed through the quarantine section of the laboratory, a total of 167,000 insects from 12 countries. A total of 62 species (157,000 individuals) were released from quarantine or reared, and were sent in 367 shipments to USDA and Federal cooperators in 23 States and 3 foreign countries. These beneficial insects were employed for the control of the gypsy moth, European corn borer, various aphids, alfalfa weevil, cereal leaf beetle, alfalfa blotch leafminer, larch casebearer, and several other pest species, all of which cause serious economic losses to crops. (Newark, Delaware)

The status of the major successful biocontrol programs (in which this laboratory has been involved) during the past year follows:

Alfalfa weevil: The use of imported parasites reduced insecticide usage by at least 50% in the Northeastern U.S. (saving growers and consumers ca. 5 million dollars), and by 20-50% in several Central States. Ca. 8000 parasites were reared at Newark, and shipped to 8 Central States for release. Surveys in the Northeast showed that one parasite species was detected in 2 additional States, and 5 species were found in a total of 89 new counties; similar surveys are badly needed in the Central States. A continuing impact evaluation at 3 mid-Atlantic locations showed that parasitism of late overwintered adult alfalfa weevils averaged (4 years) 40%, 37% of the resulting larvae were parasitized, and 20% of the new weevils were parasitized, for an adjusted total population parasitism of 60%. Gypsy moth: Continuing evaluation of the impact of introduced parasites in Northeastern forests indicates that parasites are responsible for suppressing populations so that outbreaks are only occasional, and that dispersion of the GM population is also much reduced. Parasitism of overwintering egg masses averaged 38%, and larval parasitism by 4 species was similarly high in older infestations. The data show that the species of parasites attacking the larval and pupal stages of the gypsy moth vary in their abundance a great deal from year to year, and also

from location to location, illustrating the soundness of introducing all safe exotic species into the U.S., and showing the need for further exploration in Japan and vicinity by the ARS Asian Parasite Laboratory. Work is also underway to improve a commercial artificial diet, to increase growth and survival of field-collected larvae (which have previously fed on oak and other foliage). Coccinella 7-punctata: About 80,000 beetles were collected at the only establishment site in the U.S., and 61,000 were shipped to 10 States, for employment against various aphid pests. Successful overwintering, in the field, was verified this spring in Delaware, Texas, Oklahoma, and Washington State. Alfalfa blotch leafminer: Several species of European parasites have been reared, and their biologies worked out, in the laboratory. About 11,000 Diglyphus isaea were released in the field, plus small numbers of 2 other species. Parasitism of leafminers by native species averaged 38%, but was insufficient to prevent excessive damage to the first cutting of alfalfa, so it is hoped that several of the European parasites can be established. The biologies of the blotch leafminer and several related species are also being investigated in detail.

Skeleton weed (Chondrilla juncea L.) occurs over a wide range on the European continent and in the U.S. along the Atlantic seaboard from Delaware into Virginia, West Virginia, and Michigan. Skeleton weed rust, caused by Puccinia chondrillina Bubak. & Syd. is found on the weed in Europe and has been reported from the above locations in the U.S. Skeleton weed is considered a pest in the Pacific Northwest and California and the rust has not been reported there. It is serious in Placer and El Dorado counties of California and in Southern Idaho, where the infestation has increased from 100 to 350,000 acres in a period of eight years. The infestation is being closely watched in Spokane and Walla Walla counties of Washington. Twenty-eight cultures of P. chondrillina were collected from Southern France and Italy. The cultures were screened against the various California clones of the weed and six of the cultures were found to be virulent on the clones tested. Uredospores of the most virulent culture have been produced and released in California. (Frederick, Md.)

With the assistance of VPI entomologists, the introduced musk thistle seed weevil Rhinocyllus conicus was collected from points of establishment in Virginia in spring 1975 and 1976, and 1180 adults were released on musk thistle in Central Maryland and Pennsylvania; 360 were released at Beltsville and 600 were sent to the New Jersey Department of Agriculture for culture and release in 1975. (Beltsville, Md.)

The literature on target weeds in Texas and their natural enemies was reviewed and indexed. The following preliminary ranking was assigned to priority target weeds: (1) broomweed (Xanthocephalum and Gutierrezia spp.), (2) mesquite (Prosopis spp.), (3) African rue (Peganum harmala), (4) baccharis (Baccharis spp.), (5) whitebrush (Aloysia spp.), (6) loco weed (Astragalus spp.), (7) creosotebush (Larrea divaricata), (8) huisache (Acacia farnesiana), (9) retama (Parkinsonia aculeata), and (10) tarbush (Flourensia cernua). A search was made in Paraguay and Brazil during January, February, and March for insects and other organisms attacking mesquite, whitebrush, baccharis, retama, huisache and Brazilian pepper tree (Schinus terebinthifolia). Several species of insects were collected from these plants and are awaiting identification. Promising candidates for introduction are two stem borers and two weevils on whitebrush, a stem borer and three species of chrysomelid beetles on baccharis, and several weevils and the larva of a seed-feeding moth on mesquite. Leading botanists, entomologists, and botanical and entomological museums were visited in both countries. Three weeks were spent reviewing the aquatic weed program at Buenos Aires, Argentina. (Temple, Texas)

Twelve shipments of tea scale parasites were received from India. A yet unidentified species of Aphytis (close to Aphytis theae) has been found in the field in Gainesville on tea scale on camellia. A greenhouse culture of Aphytis has produced 75% parasitism of male tea scale and 4.6% parasitism of female scale. (Gainesville, Florida)

The twig mining lepidopteran, Coleophora parthenica (Pakistan), is well established on Salsola iberica (Russian thistle) near Kettleman City (CA), Indio (CA), Bakersfield (CA), and Tracy (CA). In some cases the larvae have killed or stunted the plants. Greatest impact occurs where the temperature is sufficiently warm to permit three generations of the moth per season. The Longitarsus jacobaeae flea beetle (Italy) continues to spread in the Ft. Bragg area (CA) and has helped reduce the rosettes of Senecio jacobaea (Tansy ragwort) to 1/100 of their pre-release abundance. The Rhinocyllus conicus seed weevil (Italy) now infests 90% of the heads of Silybum marianum (milk thistle) at the original Contra Costa Co. (CA) release site and has reduced seed number by about 2/3. This same weevil was collected from established colonies on Carduus nutans (musk thistle) in Virginia and Montana and distributed to 16 States for the control of this weed. The crown mining weevil, Phrydiuchus tau (Yugoslavia), is well established on Salvia aethiopis (Mediterranean sage) near Lakeview, Oregon. The fly, Urophora affinis (France), was released on diffuse and/or spotted knapweed (Centaurea diffusa, C. maculosa) in Washington, Montana, Oregon and Idaho. The fly is established at several sites on both plants. Releases of Hyles euphorbiae (Switzerland) and Chamaesphecia empiformis (Austria) were made on Euphorbia esula (leafy spurge) in several States. (Albany, California)



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TO 2. New and improved technology for increase and conservation of introduced and native biological agents for control of insects, weeds, plant pathogens, and other pests.

Selected Examples of Progress for FY 1976

A cooperative program with 12 scientists from ARS, FS, State, and foreign laboratories was organized, in which formulations of over 300 isolates of B. thuringiensis were prepared by the Brownsville laboratory and tested against 20 species of insects, mostly Lepidoptera, but including the horn fly, goat louse, and 4 species of mosquitoes. A workshop, attended by all participants and representatives of several industries, was held in Brownsville to review progress. Data indicate that there is a close correlation between the serological classification of the variant of B. thuringiensis used to produce an endotoxin and the spectrum of activity of the endotoxin it produces. Isolates were found that were superior in the laboratory to HD-1 (the strain of B. thuringiensis used commercially in the United States) against any given insect tested. This indicates that no one endotoxin may be best for the control of all lepidopterous pests. The reference standard developed for use in bioassaying formulations of HD-1 may not be homologous with HD-1. This indicates the desirability of replacing this standard with a new one. A satisfactory assay has been developed to measure the potency of formulations of the Heliothis virus. We have also shown that an accurate bioassay requires a comparison with a standard virus preparation, but that such a preparation may not be stable if stored at room temperature or in the refrigerator, but is apparently stable when stored in a freezer. (Brownsville, Texas)

Microencapsulated preparations of Bacillus thuringiensis (B.t.) spores and paraspores are effective against Japanese beetle larvae when force fed. Control of the insect through natural feeding with encapsulated B.t. should also be effective, but this was not proven due to complications arising with the test larvae. Coleopteran larvae when actively feeding do have a sufficiently alkaline mid-gut pH to support dissolution of the paraspore. Japanese beetle larvae in Phases III or IV of the milky disease are highly susceptible to fungal spores of various genera including Entomophthora and Nomuraea. Milky larvae incubated in the presence of any of the fungi tested at concentrations of 1-4 billion spores per gram of soil died within 5-7 days, while milky larvae not placed in a fungal environment survived for at least 25 days. Initial attempts to measure the effect of soluble B.t. endotoxin protein upon potassium transport in yeast mitochondria were inconclusive. due in part to difficulty encountered in the isolation of intact, respiring mitochondria. Potassium translocation has not been observed in yeast mitochondria treated with solubilized endotoxin protein, nor has potassium ion movement been stimulated in these preparations by adding valinomycin.

Electrophoretic studies of alkaline-solubilized endotoxin protein revealed multiple subunits as small as 20,000 MW. However, the subunits were poorly resolved and there were indications of non-proteinaceous material migrating near the front. (Peoria, Illinois)

Cabbage looper larvae, Trichoplusia ni, were equally susceptible to isolates of the entomogenous fungus Nomuraea rileyi from Missouri, Mississippi, and Brazil; an isolate from Florida was 7 to 17X less active than the others. Velvetbean caterpillars were not, or only slightly, susceptible to N. rileyi isolates from Missouri, Florida, and Mississippi; however, larvae cultured in Missouri, Florida, and Brazil were equally susceptible to a Brazilian isolate of N. rileyi. Inoculative releases of T. ni larvae on soybean plants treated with a single application of N. rileyi in cages enabled the initiation and continuation of an epizootic. Similar caged plants treated with the fungicide Benlate had significantly less infected larvae and more foliage; no differences occurred in yields between plots. A commercial adjuvant provided protection against inactivation of the Heliothis sp. NPV by sunlight retarded evaporation and acted as a gustatory stimulant for Heliothis zea larvae. The adjuvant increased stability 2 to 11X and increased feeding ca. 3X. Four new commercial formulations of the NPV were more active and stable than previously tested formulations. Effects of Bacillus thuringiensis, nucleopolyhedrosis virus, and N. rileyi on H. zea larvae feeding on soybeans in cages were determined. Four applications resulted in the following larval control: BT, 69-96%; virus, 92-100%; and N. rileyi, 19-77% control. Relative susceptibility of 6 species of soybean caterpillars to a standard isolate of B. thuringiensis was determined. Evaluation of discrete droplet sizes, densities (no./unit area), and concentration of formulations containing Bacillus thuringiensis and Baculovirus heliothis indicated that larval mortality was a function of application rate. Differences between 2 formulations of BT (Thuricide 16B and HPC) based on larval mortality were indistinguishable through standardized bioassays. Detectable quantities of Baculovirus heliothis (via bioassay) were deposited on pods located at the bottom 1/3 of treated soybean plants. Droplets of 137  $\mu$ m (VMD) produced highest larval mortalities. Microbial formulations containing evaporation retardants generally provided the best coverage. Samples of recently developed commercial WP formulations of Baculovirus heliothis are more stable when exposed to artificial and natural sunlight than previously available formulations. A commercial microbial insecticide adjuvant provided significant protection from UV radiation, retarded evaporation, and acted as a gustatory stimulant when included in microbial formulations. Grape berry moth populations were monitored by pheromone traps, and larval populations were sampled throughout the season. A commercial preparation of Bt (Dipel SP, 1/4#/acre) provided effective control on catawba grapes (0.27% damaged berries and a 19% increase in yield). In caged tests, Podisus maculiventris released at 3 rates (0.5, 1.0, and 2.0 4th-instars/row-ft) against Heliothis zea (3rd-instar, 50/row-ft) provided the following levels of control: 0.5, 17%; 1.0, 30%; and 2.0, 54%. Three biological insecticides were evaluated in cage tests

against H. zea larvae at the following rates: Bt (Dipel) at 1/2, 1, 2, and 4#/acre; Heliothis NPV (SAN 240 WP) at 1, 10, 50, and 100 LE/acre; and Nomuraea rileyi at 0.1, 1.0, 10.0, and 100.0g of spores/acre. Four applications gave the following population reductions: virus, 92-100%; Bt, 69-96%; and Nomuraea, 19-77%. Insect growth regulators TH6040 and TH6042 applied to caged soybeans against 3rd-instar H. zea (15/row-ft) at 3 dosages (0.2, 0.5, and 2.0 lb/acre) did not affect population levels or soybean yield. In alfalfa and soybean, 4 chemicals (eugenol, methyl eugenol, anisylacetone, dipentylamine) did not provide significant attraction to released populations of Chelonus blackburni, Trichogramma pretiosum, or Chrysopa carnea adults. Effects of biweekly applications of chemical or biological insecticides or interplanted alfalfa on arthropod populations in soybeans were evaluated. Core samples and pitfall collections collected 184 spp. of soybean soil arthropods. Parathion applied at full flowering decreased populations of predators on plants, resulting in doubling of number of lepidopteran larvae 5-8 weeks later. Row width, tillage, herbicide application, and planting date affected populations of soybean arthropods in year 2 of a 5-year study; combined simple effects or interactions were often 10X and up to 95X. A calibration ratio was established between sweep-net and D-Vac collections. Procedures devised for separating arthropods from debris were evaluated. Survival of cabbage loopers in the field from eggs to mid-5th instar was less than 0.1%; survival of velvetbean caterpillars was 0.7-3.3%. Predators of Rubidium-marked cabbage looper larvae were identified by flame emission spectroscopy. Capability of 241 species for preying upon cabbage looper larvae was tested in the laboratory. Podisus maculiventris responds more to late-instar larvae in the field than to early instars; laboratory tests demonstrated that the response is due to a kairomone. Orius insidiosus has been continuously reared in the laboratory on fresh or frozen cabbage looper eggs which are better than spider mites as a food source. An ovipositional substrate was developed to obtain large numbers of Trichogramma eggs. An artificial diet supporting complete development of Trichogramma was formulated. Six piercing-sucking insects have been reared on capsules filled with insect blood plasma (four of the six species completed development). Mean seasonal parasitization of green cloverworm populations in soybean ecosystems in 1975 was 58%. The parasites Rogas nolothonae, Apanteles marginiventris, Protomicroplitis facetosa, Winthemia sinuata, and the fungus Nomuraea rileyi were the dominant species and accounted for over 90% of the parasitization. R. nolothonae attained higher levels of parasitization in 1975 than in previous years, primarily at the expense of N. rileyi. Weekly applications of Sevin (1/16 # A/A) to soybeans from growth stages VI-R8 eliminated green cloverworm populations. Conversely, Benlate (1/2 #A/A) during the same period had no effect on the pest population. Benlate-treated plots showed a 15% reduction in parasitism when compared to a check. When spraying was discontinued, no differences were recorded. Biotic agents associated with pest insects of soybeans were collected on a TDY assignment to Brazil and Colombia, South America. Included were some undescribed species of parasites that have potential for introduction into the U.S. One Euplectrus sp. nr. comstockii was received in quarantine and is being



propagated for study and release against the velvetbean caterpillar. Introduced parasites of the alfalfa weevil were not recovered nor were any pathogens. Parasitism by Bathyplectes curculionis was lower than recorded previously. Conclusive evidence of mixed or interbreeding populations of eastern and western strains of the weevil was not established in Nebraska. Meteorus leviventris, Campoletis flavicincta, Bonnetia compta, Microplitis feltiae, and Heraermis arvalis were reared as parasites of the black cutworm. The fungus N. rileyi was recovered from overwintering larvae of the black, dingy, and spotted cutworm. Black cutworms were not readily susceptible to two viruses of a related species obtained from the Soviet Union. Apanteles marginiventris prefers neonate (0.03 mg) and 1st-instar (0.28 mg) larvae as hosts. Large populations (ca. 150/row-ft) of neonate, 2nd-instar, and 4th-instar larvae of Heliothis zea, Trichoplusia ni, and Pseudoplusia includens appear to attract indigenous populations of predators and parasitoids in soybeans. Results of a laboratory study indicate that Podisus maculiventris is least successful in utilizing Anticarsia gemmatalis for food due to the vigorous way in which the larvae defend themselves. Larvae of Heliothis zea, Trichoplusia ni, and Pseudoplusia includens, while responding strongly to predator attack, were significantly more vulnerable. Rearing procedures and a semisynthetic diet were developed for culturing the velvetbean caterpillar, Anticarsia gemmatalis Hübner. The inheritance of resistance to 2nd-instar cabbage looper feedings was determined in the field with progeny from crosses of the resistant parents P.I. 171,451 and P.I. 229,358 and the susceptible parents Amsoy 71 and Beeson. Heritability estimates from the  $F_3$ - $F_4$  progeny ranged from 6 to 44%. A water-pheromone trap baited with the synthetic sex pheromone of adult cabbage loopers, Trichoplusia ni (Hübner), caught many more male looper moths in the field than a blacklight trap baited with looper pheromone and screen-type pheromone trap. (Columbia, Missouri)

Growth and primary isolation of four corn stunt (CSO) strains was deleteriously affected by deletion of organic acids, inorganic salts, replacement of amino acids by lactalbumin hydrolysate, or an osmolality of 300 mOsm in MIA medium. Alphaketo-glutaric acid appeared essential for optimal CSO growth. Growth of four strains of S. citri was reduced greatly by deletion of the defined amino acid constituent, but not by most factors limiting CSO growth. Suitability of spiroplasma medium formulations was dependent on certain medium constituents. A fourth spiroplasma group was discovered by inoculation of egg-passaged suckling mouse cataract agent (SMCA) into embryonated eggs. Motile, helical wall-free organisms were found by dark field microscopy in egg fluids post-inoculation. Electron microscopic observations, including negative staining and examination of thin sections confirmed the spiroplasmal nature of the agent. As tested serologically by ring precipitation or organism deformation tests, the new spiroplasma was serologically related to, but not identical with Spiroplasma citri, the agent of sex-ratio abnormality in Drosophila, and the CSO. Studies on the toxic action of B. thuringiensis  $\delta$ -endotoxin revealed that the

cessation of uncoupling of ATP production in the mitochondria of susceptible insects is closely correlated with release of respiration and proton transport, i.e., the toxin acts by promoting electrogenic hydrogen ion transport across the mitochondrial inner membrane. Attempts to sporulate B. popilliae in media, anaerobically and aerobically, using steady state cultural techniques were unsuccessful. Metabolic studies to determine the catabolic efficiency revealed that under strict anaerobic conditions the organism utilizes a fermentative energy production system. Preliminary analysis of cell mass/substrate utilization/energy production data under semi-aerobic conditions revealed that  $O_2$  is not utilized as the terminal electron acceptor. Presumably, the  $O_2$  uptake measured was the result of a superoxide dismutase system. Methods were developed for the decontamination of insect rearing facilities and equipment by the use of the fumigant ethylene oxide. Large-scale field tests in cooperation with the States of CT, NJ and VA have shown the efficacy of this treatment. Two forms of envelope nucleocapsid (ENC) were defined: 1 invasive form ENC occluded in nucleus, 2 hemocoelic, intercellular infective unit, enveloped with peplomers. Peplomers form on one end only ENC in cell leave with envelope formed from nuclear or cell membrane. All insect cell lines here serologically characterized and placed as to species of origin. An antisera bank was prepared to permit checking on validity of cell lines. Studies on in vitro insect cell nutrition have resulted in a serum-free medium for culture of insect cells and insect viruses production. Early sterol studies confirmed the need to have lipid free medium in order to study lipid metabolism in insect cell cultures. Dalipidized serums were used to develop lipid free medium which was then applied to determine the effectiveness of added lipid(s). Cells grown on Dalipidized medium gave limited growth responses, however, addition of required lipids stimulated growth development approaching that of the controls on normal serums. Plaquing studies of the non-occluded virions of a Baculovirus in cultured cells showed a low percentage (2-0%) of cells initially infested. Virions optimally attach to cultured cells at pH 7.0. Attachment reduced 50% when virus incubated at  $4^\circ C$  than at  $23^\circ C$ . Time kinetics showed initial adsorption was less and with characteristic slope. Chemical work showed MG ++ and Ca ++ were most effective ions in promoting adsorption. Larval equivalents (L.E.), 9900 of the A. californica nuclear polyhedrosis virus (NPV) were dispersed among eight collaborators in La., Mo., Pa., S. C., Va., Ark., N. Y., and Ont. Can. Most of the tests were row test on one-tenth acre of cabbage. One test was carried out on soybeans and one late test on H. virescens on cotton. All but two tests, S. C. and Ark. gave good control and equal to the chemical pesticide used. High doses (50 and 100 L.E./acre) were used to offset the fact that the virus was unformulated. A petition to EPA for a Temporary Exemption from a Requirement of Tolerance and a special permit is in preparation. An additional cell line which grows on a less expensive medium was tested and found suitable for use in roller bottle cultures. Tests on ratio of virus to cell culture number established that increased yield can be obtained by increasing the ratio. (Beltsville, Maryland)

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TO 3    New and improved principles and practices of insect and mite identification

Selected Examples of Progress for FY 1976

A revision was completed of Leptoconops, a large group of biting gnats from Western North America. Studies on the taxonomy of other biting gnats important as biological control agents of other insects, vectors of diseases and pollinators of cacao were also completed. A taxonomic study was made of the 13 gall midge species, seven new to science, of Eupatorium odoratum, a weedy tropical American plant introduced into Asia and Africa. Some of the midges are potential biological control agents. Two new South American fruit-flies of the genus Anastrepha were described. One is a pest of Colombian zapote, a food crop. A taxonomic revision of the chalcid genus Chalcis for Mexico was completed. All species are important parasites of flies in the family Stratiomyidae. A study was completed on the Aphidius species parasitic on the pea aphid in North America. As a result, the nomenclature and correct identity of these important parasites is settled after many years of confusion. A catalogue of the species of the world of the braconid subfamily Doryctinae was published as part of the Hymenopterorum Catalogus being published in Europe. A book concerning the sphecid wasps of the world was published. As a result, this large group of wasps is placed on a sound taxonomic basis and means of identifying the genera are made available in one place. A brief description and note on a gall wasp from the Orient found in North America was published. This wasp is of potential harm to chestnuts grown in the Southeastern U.S. An aid to the identification of an Asian horntail found in North America was published. This wasp was found boring in water oak in Alabama and is the first documented case of the introduction and establishment of an Asian siricid in the U.S. A manual written for technical presentation to APHIS port identifiers, on distinguishing features of woodboring Coleoptera frequently intercepted at U.S. ports, was published. Text and over 200 line drawings have been completed for Fascicle 6.1 of the Moths of America North of Mexico. Two major lines of work are included: a reassessment of the family and subfamily classification of the Gelechioidea and a revision of the nearctic moths of the family Cosmopterigidae with subfamilies Cosmopteriginae, Antequerinae, and Chrysopeleiinae. Forty-seven family-group taxa, 26 genera (2 new to science), and 180 species (45 new to science) are treated. A revisionary study was completed that will make possible the identification of notodontid moths of the genus Dunama, a tropical American group that includes pests on ornamental plants and banana. Completed was the balance of the work covering the North American Orgyiidae, the family that includes the gypsy moth, Douglas-fir tussock moth, and other important pest species. This paper has been submitted for publication as Fascicle 22.2 of The Moths of America North of Mexico series. It consists of about 300 manuscript pages, 8 colored plates, and numerous text figures. Identification keys were completed for the genera of anthocorid bugs of the United States and Canada. These are predators of major significance in the control of aphids, chermids and thrips, and

their introduction into new areas for biological control increased the need for such keys. In response to a request for a name from an outside researcher, a new genus and species of mirid plant bug were described. This bug is predaceous on fungus-feeding beetle larvae. Taxonomic revisions were completed for the neotropical planthoppers (Homoptera, Fulgoroidea) of the genus Bladina (21 species), and for the species of the planthopper genus Oecleus that occur in the United States (41 species). As planthoppers are entirely phytophagous and often extremely abundant, they are judged to be of prime importance to agriculture. During the year three research papers on scale insects have been published including taxonomic studies on the poorly known mealybug genera Heterococcus and Stemmatomerinx. All instars of three mealybugs were examined in detail and it was determined that their unusual morphological similarity is due to convergent evolution, not to ancestral relationships. Keys were constructed for ARS scientists, State entomologists, and university personnel to aid in the identification of aphids collected in yellow pans and sticky traps. The research of over ten different projects is dependent on these keys. A detailed taxonomic treatment of the thrips of the Frankliniella minuta group is complete. These thrips are New World flower inhabitants which may disfigure flowers and fruit, aid in pollination, or transmit viruses. A species of tarsonemid mite is described that feeds on the eggs of two plant feeding mites; this is the first record of a tarsonemid feeding on mite eggs. A book was published on mites injurious to economic crops of the world. It includes detailed information on mite biology, control, and taxonomy.

A total of 89,420 service identifications were made from 299,951 specimens examined; 56,245 specimens were added to the U.S. National Collection. Identifications were made for: APHIS - 13,132; ARS - 28,113; FS - 1,587; other Federal organizations - 1,206; State organizations - 12,015; U.S. individuals - 17,376; foreign organizations - 15,991.

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NRP Annual Report  
FY 1976

NRP 20270 Crop Disease Control and Non-Commodity Research on Plant  
Pathogens and Nematodes

NPS Contact: W. M. Dowler

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NEMATOLOGY

T01: Acquire fundamental knowledge and develop basic concepts relative to plant disease, nematodes, and causal agents.

Baton Rouge, LA (Birchfield): Morphology studies of the Wartelle race of root-knot nematode showed that it has physical characteristics that may group it as a new species or subspecies. The biology of a new species of root-knot nematode, Meloidogyne graminicola, was elucidated. The host range of Heterodera graminophila, a new cyst nematode in this area, was extended.

The morphology and means of host penetration of the protozoan, Duboscqia penetrans, was studied with the scanning electron microscope. Chloromycetin was found to be effective against plant nematodes. This is the first record of antibiotics being effective against nematodes and may be important to medical science as well as agriculture.

Beltsville, MD (Endo, Golden, Nickle, Rebois, Sayre, Wergin): In a taxonomic review of several Heterodera species, H. thornei from California was described as new, H. weissi was redescribed with types designated, and extensive new data on H. cacti, H. amaranthi, and H. estonica was given. Many new areas and countries of occurrence are reported for most of these cyst nematodes. Common names and a key for species identification also were presented. Vulval denticles, teeth-like structures in the cyst cone, were for the first time described and named. H. betulae was placed in a separate new group.

A root-knot nematode which attacks all resistant soybean varieties in Louisiana is under study as a probable new subspecies of Meloidogyne. M. naasi (barley root-knot nematode), Pratylenchus agilis (root lesion nematode), and a Meloidoderita species, the latter previously known only in Russia, were found in Maryland. Nematodes from about 375 samples were identified for research, regulatory and control purposes, resulting in discovery of 5 new species representing new potential diseases.

Reniform nematode resistance was found and confirmed in one commercial and two experimental potato lines. The two experimental lines also have resistance to the golden nematode of potatoes. Separate genes appear to impart reniform and golden nematode resistance in potatoes. Crosses between reniform nematode resistant and susceptible tomato lines indicate there is at least one dominant gene for resistance in PI 375937.

Two rates of aldicarb, carbofuran, and ethoprop were applied to soybeans, in normal producing areas, at two field locations. Aldicarb at the high rate significantly increased yields by an average of 20.2%. Yields were negatively correlated with root lesion and with total nematodes in the soil. Neutral sterol analysis of reniform nematodes indicated that this nematode probably cannot synthesize cholesterol from smaller molecules but must obtain this and other sterols from larger or related compounds in their hosts.

The bacterial parasite, Bacillus penetrans, of the root-knot nematode Meloidogyne incognita was examined with scanning and transmission electron microscopy. The complete life cycle for the bacterium within the nematode was elucidated. Briefly, the parasites' infective stage, an and endospore, attaches to the nematodes surface. A germ tube penetrates the cuticle, and forms numerous mycelial colonies which then fill the nematodes' body with vegetative cells.

Work continued on the utilization of sewage sludge as a soil organic amendment to determine its nematicidal effects on the root-knot nematode, Meloidogyne incognita. In field tests, the incidence of nematode galling was significantly reduced where raw sludge was applied, but not where equivalent amounts of composted sludge was used. An additional isolate of a Catenaria sp., a phycomyceteous fungus attacking root-knot nematodes, was found and isolated.

Current research involves an ultrastructural examination of the anatomy of larvae of the root-knot nematode, Meloidogyne incognita, and the soybean cyst, Heterodera glycines. An attempt is being made to correlate nematode anatomy, feeding, and host responses in susceptible and resistant plants. The emphasis on the sensory organs of the root-knot nematode is a contribution toward the major goal of defining changes which occur in both the parasite and the host during nematode infection of crop plants.

W. P. Wergin has a joint appointment with the Nematology Laboratory, PPI, and Reproduction Laboratory, APGI. He has extended an ultrastructural program in nematology by examining the fine-structure of nematode parasites in cooperation with Richard Sayre, and by investigating the potential application of scanning electron microscopy to other research programs in the laboratory.

Data on the taxonomy, biology, and life cycles of four nematode parasites of insects in a tributary of Beaver Dam Creek were collected. The black fly mermithid Neomesomermis fluminalis was collected in upper New York state and released in a black fly stream at BARC in a classical release in hopes for establishment.



Mermithids infected about 60% of the grubs from one area of the towngreen at Brattleboro, Vermont; and 16% of the grubs at the Wallingford, Connecticut Country Club. Grubs became infected in late summer with the nematodes emerging the following May.

Charleston, SC (Fassuliotis): Fifteen day old heart-shaped embryos were excised from crosses of Cucumis metuliferus x C. melo 'Gulfstream' cantaloupe and C. anguria x 'Gulfstream' and raised to whole plantlets: four from the C. anguria cross and six from the C. metuliferus cross. Only one plant from the latter cross survived, grew vigorously in the greenhouse and produced fertile fruit. The F<sub>1</sub> plant had all the characteristics of the maternal parent and no segregation was observed of the S<sub>1</sub> generation.

Some progress has been made in somatic hybridization of nematode resistant and susceptible plants. Protoplasts from root-knot resistant Solanum sisymbriifolium and eggplant, S. melongena, were fused and new cell walls regenerated but no cellular divisions occurred.

Attempts to culture root-knot nematodes on callus as a means for maintaining populations for extended periods were unsuccessful. An alternative method of raising root-knot in vitro was investigated. A complete life cycle of M. incognita under aseptic conditions on 'Charleston Gray' watermelon cotyledons was obtained. This method for culturing root knot nematodes is being investigated further.

College Station, TX (Veech): The concentration of total terpenoid aldehydes and of five specific terpenoid aldehydes (hemigossypol, methoxy-hemigossypol, gossypol, methoxygossypol, dimethoxygossypol) was greater in healthy root-knot susceptible (Deltapine 16) cotton roots than in healthy root-knot resistant (Auburn 623) roots. Concentrations of these terpenoid aldehydes increased in both varieties as seedlings aged but only in the resistant variety as a result of infection by Meloidogyne incognita. However, the susceptible variety still contained more of each of the specific terpenoid aldehydes at 2-10 days after inoculation than the resistant variety. The terpenoid aldehydes are currently being tested for their toxicity of M. incognita. A histochemical investigation of terpenoid aldehyde localization in susceptible and resistant cottons is in progress.

The Gossypium hirsutum geographical race collection is being evaluated for resistance to M. incognita; approximately half the collection (400 strains) has been evaluated. A study to determine if nematodes were involved in "crazy cotton" in Mississippi has been completed. No involvement was observed.

Ithaca, NY (Brodie): The reproductive capacity of the potato cyst nematode, Heterodera rostochiensis, was significantly greater in muck and clay loam (Steuben County) than it was in sandy loam (Long Island) soil. However, development of H. rostochiensis was somewhat slower in muck (42 days from egg to egg) than it was in clay loam and sandy loam (32 and 34 days from egg to egg, respectively).

Equal numbers of H. rostochiensis larvae entered roots of golden nematode resistant and susceptible cultivars. Significantly more larvae of Meloidogyne incognita were found in root-knot susceptible than in resistant potato clones. Resistance to M. incognita in Solanum tuberosum spp. andigena is associated with severe necrosis of root tips. Vertical downward movement of aldicarb was greater in mineral than in muck soil.

Logan, UT (Griffin): Greenhouse studies with nonhost plants showed that sweet spanish onion and bush bean have a positive effect on hatching of the sugarbeet cyst nematode and reduced the nematode population below that of fallowed soil. Barley, wheat, and alfalfa were less effective at reducing the sugarbeet nematode population. Initial reduction of the sugarbeet nematode population by sugarbeet plants was not as drastic as one would expect, indicating that there is not an immediate hatch of most or all of the larvae soon after sugarbeet seed is planted.

Early planted beets, planted before the soil temperature reaches 10 C, produce greater yields than do those planted at 10 C or above because of the accelerated infection of sugarbeet by the sugarbeet nematode at temperatures above 10 C.

The northern root-knot nematode infects both resistant and susceptible alfalfa selections and cultivars. However, nematodes soon migrate out of resistant plants leaving no noticeable histological effects. The degree of infection and infectivity time in resistant plants are dependent on the proximity and confinement of the inoculum in relation to host roots.

A Utah population of the northern root-knot nematode, Meloidogyne hapla, was able to infect M-4, a previously reported immune Vernal alfalfa selection.

Lubbock, TX (Orr): Fundamental research of the biology, pathology, and economic importance of the nematode Nothanguina phyllobia parasitizing silverleaf nightshade indicates a strong probability that the nematode can be incorporated as a biological control in a program to control this troublesome weed.

Studies were initiated to elucidate the biology and pathogenicity of nematode Diplogasteritus labiata found associated with carrot beetle larvae. The bacteria Pasteurella and Serratia were isolated from the nematode infested beetle larvae.

Research has shown that nematodes and fungi combine to form an important disease complex. Studies have been initiated to gain new knowledge in this area.

Salinas, CA (Steele): The hatch factor in sugarbeet root diffusate has been obtained in a nearly pure state and appears to be an acidic compound containing sulfur and nitrogen with a molecular weight of 3000 to 4000. Treatments with 500 µg/ml AC 64,475 permanently inhibited hatching of Heterodera schachtii, whereas lower concentrations only temporarily inhibited hatching. Concentrations of carbofuran in excess of 50 µg/ml completely but only temporarily inhibited hatching.

Shafter, CA (Jorgenson): Nematode-tolerant-resistant cotton strains developed at Shafter will withstand initial population levels of cotton root-knot nematode 10 to 100 times higher than those tolerated by commercial varieties. Additionally, because the reproductive rate of the nematode was lower on these resistant lines, longer time was required for the nematodes to increase to damaging levels. The carrying capacity of these cultivars exceeded the reproductive rate of the nematode for three years. These cultivars, or commercial varieties containing the same type and level of resistance, should not be grown more than three consecutive years without fumigation or other nematode control. Present commercial varieties require annual control of nematodes.

Fusarium wilt-root-knot nematode complex disease of cotton was controlled in a greenhouse experiment with aldicarb at 2.0 and 0.2 µg/g soil. Nematode numbers were reduced by only 40 percent with these treatments as compared to untreated controls. Treatments with lower amounts of aldicarb reduced root-knot nematode numbers comparatively less, and did not control the fusarium wilt-root-knot nematode complex disease. It is not likely that a simple 40 percent reduction of root-knot nematode numbers is the sole cause for control of this disease complex. There are other interrelations which remain to be discovered.



Urbana, IL (Edwards): Studies of the comparative host-parasite relationships of 7 species of Pratylenchus on soybean were initiated. P. vulnus and P. coffeae, not previously reported as parasites of soybean, readily reproduced on Clark-63. The optimum temperature for population development of P. scribneri and P. alleni on soybean was 34 and 26 C, respectively. High populations of these species caused considerable reductions in plant weight, while moderate to low levels did not significantly affect growth during one cropping season.

Race 4 of the soybean cyst nematode (Heterodera glycines) was found in 4 Illinois counties and constitutes approximately 10 percent of the total infestation. Encysted H. glycines survived subfreezing temperatures ranging from 0 to -30 C. Development from cysts exposed to -30 C was significantly greater than those exposed to higher subfreezing temperatures.

Weslaco, TX (Heald): Light reflectance of cotton plants and leaves was measured in reniform nematode infected and non-infected plants in the field and greenhouse. Leaves of nematode infected plants had a lower reflectance than did those of non-infected plants. These differences were caused by difference in chlorophyll concentration, mesophyll structure and water content which indicated the potential of using remote sensing techniques for distinguishing nematode infested plants from normal plants.

NEMATOLOGY

T02: Develop systems for economic control of plant diseases and nematodes with maximum beneficial effects on yield and quality, and minimum undesirable effects on the environment and public health.

Baton Rouge, LA (Birchfield): Thirteen hundred breeding lines and/or soybean varieties were tested for resistance to the Wartelle race of root-knot nematode, Meloidogyne incognita. A few were more resistant and produced more soybeans than our best commercial variety (Bragg). The most resistant breeding line is D69-3364 which is also the highest yielding selection.

Pickett, Pickett 71 and Forest soybean varieties were the most resistant varieties tested against the reniform nematode, Rotylenchulus reniformis. They produced 5-10 bushels more beans per acre than the susceptible Bragg and Lee 68 variety now being grown.

The new type organophosphate and carbamates controlled reniform and root-knot nematodes on soybeans. However, soybean production was not increased with any of the nematicides that were tried.

Seventy-four sugarcane breeding lines and/or varieties were tested for resistance to root-knot nematode, M. incognita. Fourteen percent of the lines tested were resistant. One resistant variety has vigor and a high sucrose content.

Nematode control and high yields were obtained with a new planting technique employing chemicals on 2nd and 3rd year sugarcane stubble. Yields were doubled in 3rd year stubble. The nematicides carbofuran, ethoprop, fensulfothion, and aldicarb were an important part of the techniques giving increased yields.

The new type organophosphate and carbamate nematicides controlled reniform and root-knot nematodes effectively on sweetpotatoes. Production of US #1 grade was increased 81, 70, 68 and 67% with granular ethoprop, liquid ethoprop, carbofuran, and UC-21865 where reniform nematode was present. The US #1 grade was increased 87, 50, and 37% with ethoprop, fensulfothion, and aldicarb, respectively, where root-knot nematode was a limiting factor.

Bryon, GA (Wehunt): Postplant applications of the nematicide DBCP (1,2-dibromo-3-chloropropane) decreased peach tree short life (PTSL) and increased fruit yield in field experiments. Criconemoides xenoplax populations were correlated positively with tree death and negatively with fruit yield, whereas Tylenchorhynchus claytoni, the only other peach parasite of widespread occurrence on the site, was not correlated with tree death or yield. Postplant DBCP treatments at 3 gal/acre applied annually have prevented tree death for 4 years.

In a replicated field trial in a PTSL site, application of 12 pounds of hydrated lime per tree site reduced the incidence of bacterial canker disease of peach caused by Pseudomonas syringae, but 1 and 6 pounds of hydrated lime had no effect on bacterial canker. Populations of C. xenoplax were greatly reduced by the 12 pound rate of lime but not by the 1 and 6 pound rate. There may be a correlation between numbers of nematodes and the incidence of bacterial canker. Greenhouse studies show that temperature and soil moisture influence populations of C. xenoplax.

More than 80 rootstock accessions have been tested with the general results that 14 accessions showed resistance to the root-knot nematodes (M. incognita and M. javanica) with reaction to the lesion nematode and the ring nematode being inconclusive. No accession was resistant to the new race of root-knot nematode recently found in Florida. In greenhouse tests, 'Lovell' supported fewer C. xenoplax than did 'Elberta' and 'Nemaguard'.

Charleston, SC (Fassuliotis): Advanced snap bean breeding lines containing genes for resistance to the southern root-knot nematode, Meloidogyne incognita, were tested at Tifton, Georgia. Six of 9 lines were highly resistant for galling response and reproduction. Advanced tomato breeding lines containing the  $M_1$  gene were evaluated for root-knot resistance and selections are currently being observed in the field.

Ithaca, NY (Brodie): The most effective means of suppressing population densities of H. rostochiensis was by growing a resistant cultivar. Treatment with carbofuran was least effective and growing a non-host crop was intermediate. These data indicate that to successfully manage H. rostochiensis at low densities, a resistant cultivar must be grown at least once in two years.

Aldicarb, ethoprop, and phenamiphos (5.6 kg/ha) significantly reduced infection of potato by H. rostochiensis when applied to the soil during planting of potatoes. Placement of the total dosages in the seed furrow resulted in the best control. These compounds significantly suppressed nematode density increase but did not significantly reduce nematode density in the soil. Foliar application of carbofuran, oxamyl, and phenamiphos to plants growing in previously treated soil did not enhance control of H. rostochiensis.

Resistance to race A of H. rostochiensis was confirmed in 6 diploid species of Solanum. Progeny of 2 and 3-way species crosses resistant to race A were evaluated in Germany and found to possess no resistance to H. pallida (old race E of H. rostochiensis). Resistance to five species of Meloidogyne was found in S. tuberosum spp. andigena. Crosses between resistant clones produced families with up to 100% of the progeny resistant to M. incognita, the most prevalent species.



Jackson, TN (Epps): A new soybean variety named Centennial with a high level of resistance to root-knot, cyst (Race 3), and Reniform nematodes will be jointly released in October, 1976, based on performance in tests in several south eastern states. Approximately 85 bushels of seed was produced in 1975 and will be further increased in 1976. This is the result of cooperation with the Stoneville, Mississippi Station.

The screening program designed to locate sources of resistance to species of Meloidogyne (Root-Knot) has been underway during the winter months and a few varieties and entries in the germplasm collections were found to have a good level of resistance to Meloidogyne arenaria. This specie has caused heavy losses to soybean yields in areas of the South.

Logan, UT (Griffin): Study was continued on optimum usage of nematicides to control the sugarbeet cyst nematode by equating yields with nematode populations as affected by environment conditions, planting temperature, and other extrinsic factors.

There was less initial larval infection in sugarbeet seedlings when the nematicide, aldicarb, was injected on both sides of the seed at time of planting than when only a single chisel was used on one side. However, there were no differences in sugarbeet yield between the two applications.

During FY 1976 germplasm of an alfalfa synthetic variety, Nevada Synthetic XX, was released for breeding purposes. It contains resistance to the northern root-knot nematode, the alfalfa stem nematode, bacterial wilt, pea aphid, and spotted alfalfa aphid. Registration is now being sought.

Registration of another alfalfa "Kayseri" (Deseret) was applied for in FY 76. This is resistant to stem nematode, downy mildew, and bacterial wilt. It is adapted to irrigated areas in the Intermountain Region.

Potato selections screened for resistance to the northern root-knot nematode, M. hapla, were all classified as susceptible.

Lubbock, TX (Orr): Two nurseries for testing genetic vulnerability to disease in cotton strains have been established. Superior selections were made from the regional collection of Gossypium and from advanced breeding lines developed at the Lubbock location. These selections showed more resistance to nematodes and disease than did Auburn 623 RNR which we used as the resistant standard.

In a comparison of nematocide applications, the conventional deep injection of fumigants gave best control with highest lint yields; however, shallow injection at planting saved a trip over the field.

Orlando, FL (O'Bannon): Five citrus nematode populations from California (2), Arizona (1), Texas (1), and Florida (1) were differentiated on 10 Citrus spp., Poncirus trifoliata, and their hybrids. One California population was statistically separate from the other populations to be considered a separate race.

Experiments comparing single or combined populations of Radopholus similis and Pratylenchus coffeae showed P. coffeae to be as pathogenic as R. similis; mixed populations were antagonistic; and there was no multiple resistance in R. similis-resistant germplasm. One hundred and twenty-five Citrus spp., hybrids and certain relatives were shown to be hosts of P. coffeae. Four of six Microcitrus hybrid selections and one Poncirus trifoliata selection were resistant to P. coffeae.

Completed the first 3-year phase of a 6-year study on the control of R. similis with a systemic nematocide. Maintaining R. similis populations 45/g root resulted in significantly greater yields than untreated control where populations were >5/g root. Evaluation of several R. similis-resistant and tolerant rootstocks showed Carrizo citrange to be highly resistant and Estes rough lemon to be highly susceptible.

Salinas, CA (Steele): Treatment of sugarbeet infected with Heterodera schachtii with aldicarb, aldicarb sulfoxide, or aldicarb sulfone prevented development of the nematode. Soil treatments of aldicarb are lethal to larvae developing within the sugarbeet roots. Heterodera schachtii failed to develop on root slices of table beet grown in soil treated with aldicarb or aldicarb sulfoxide. Similar treatments with aldicarb, sulfone, or oxamyl did not affect nematode development.

Field experiments established that aldicarb, carbofuran, and phenamiphos effectively controlled Heterodera schachtii on sugarbeet at rates recommended by the suppliers. Nematode control increased yields of beets and sugar. Although dasanit controlled H. schachtii, this material was extremely toxic to sugarbeet and greatly reduced yields.

Shafter, CA (Jorgenson): Field experiments with fumigant and systemic nematicides in varying rates and combinations showed again the superiority of fumigants for controlling rootknot nematode on cotton. Yields from fumigated plots averaged 25 percent higher than those from untreated plots whereas yields from systemic treated plots averaged only 7 percent higher in one test, and 16 percent in another.

In the continuing search for the best way to use systemic nematicides, seed, in-furrow at planting, and mid-season side-dressing treatments of cotton with systemic nematicides resulted in very small yield increases, obviously because only minimal nematode control was achieved.

Tifton, GA (Johnson, Minton): Yields of summer squash, cucumber, tomato and pepper were increased 3 to 4-fold by using a broad spectrum soil fumigant, film mulch, and trickle irrigation. Multiple cropping within the system where additional N and K are injected through the trickle irrigation tubing has shown that up to three crops of cucumber can be grown with adequate protection from nematodes and fungi from the initial soil fumigant. Total marketable yield from three crops of cucumber was 2247 bu/A in plots treated with methyl bromide-chloropicrin and 332 bu/A from nontreated plots. The large yield increase was attributed primarily to the control of root-knot nematodes and soilborne fungi.

Yield of field corn was increased 32% to 122% when nematodes were controlled. Nematicides impregnated on fertilizer granules or in a fluid fertilizer suspension effectively controlled root-knot nematodes on tobacco. Tests on turf grasses indicated that quality (sod density and greenness) can be greatly improved by controlling nematodes.

Nematode data from an integrated pest management program with intensive cropping sequences indicate that populations of nematodes are suppressed by turnip and wheat but increase readily on southern pea, cucumber, soybean and field corn. Rye is an excellent crop to use to suppress populations of ring nematodes. Fallow and pigeon pea were more effective than millet, crotalaria, soybean and milo in suppressing numbers of root-knot nematodes.

Selected lines of Serala and Interstate sericea lespedeza varieties were resistant to Meloidogyne incognita acrita in field tests. Progeny from Ala. L10 selected from segregating populations were homozygous resistant to M. incognita acrita in greenhouse tests. Dry matter yields of kenaf (J-1-113 and Everglades 71) and roselle (A59-56) were negatively correlated with root-knot indices and nematode larval counts.

Yields of McNair 800 soybeans in 1975 were an average of 57% greater in plots subsoiled and treated with DBCP in 1974 than control. All DBCP treatments (12.1 lb/A) involving depth of placement and distance from soybean row in soil infested with Hoplolaimus columbus or M. incognita gave yield increases. However, ethoprop in these experiments at 4 lb/A applied in 18-inch band and incorporated 4-6 inches deep was ineffective.



In a split plot test in soil infested with M. arenaria, DBCP 9 lb/A and carbofuran 4 lb/A gave higher peanut yields than ethoprop 4 lb/A for Tifspan, Florunner, and Florigiant varieties. Average yield of Florunner was 881 and 492 lb greater than Tifspan and Florigiant, respectively.

Urbana, IL (Edwards): The nonvolatile organic phosphate and carbamate nematicides did not increase soybean yields significantly although they substantially increased midseason growth of soybeans. Dibromochloropropane (DBCP) at 3 and 5 quarts/acre gave effective and economical control. The yield of the resistant variety, Custer, was substantially higher than DBCP treated soybeans. Resistant varieties still offer the best control measure.

The date of planting can drastically influence the yield of soybeans on land infested with H. glycines. Yields of 'Williams' planted between May 21 and June 18 did not differ significantly, but plantings made after June 18 yielded considerably less. The resistant variety, Custer, yielded better when planted between May 21 and June 4.

Weslaco, TX (Heald): Soil fumigation controlled the reniform nematode and resulted in a significant yield increase in tomatoes, cantaloupe, okra, and southern peas but not watermelons when fumigated plots were compared to non-fumigated plots. Sunflowers also showed a significant increase in fumigated versus non-fumigated plots.

The burrowing nematode was found in ornamental nurseries near citrus orchards. Research was instituted to determine if it is the citrus or banana race of Radopholus similis. A new species of nematode was found feeding on mesquite roots and described by a taxonomist as Gracilacus latecens N. sp. Greenhouse studies of nematode control with sodium azide showed the material to be significantly more phytotoxic to tomatoes at pH 7.8 than at pH 5.1 which explains the difference in performance of the material in various parts of the area.

A standard shank application (12 inches deep, 2 weeks before planting) of DD at 12 gal/A controlled the reniform nematode and significantly increased cotton yields when compared to non-fumigated plots, as did DBCP applied 2 weeks before planting at a rate of 2 gal/A with shank injection, or in irrigation water. DBCP applied in irrigation water 54 days after planting, when reniform nematode injury in cotton was evident, also significantly increased cotton yields, but to a lesser extent. From 102 breeding lines tested for reniform nematode resistance or tolerance, 18 were selected for further testing.

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CROP DISEASE CONTROL (NON-COMMODITY)

TO1: Acquire fundamental knowledge and develop basic concepts relative to plant diseases, nematodes, and causal agents.

Beltsville, MD

Mycology Laboratory (Batra, D. Farr, M. Farr, Lentz, McKnight, Uecker):

An index of approximately 120 host species and varieties attacked by Monilinia was prepared based on provisional examination of 800 fungus collections. Fifty eight isolates of M. fructigena, M. laxa, and M. vaccinii-corymbosi were characterized taxonomically. A significant result of this work, subject to further verification, is the discovery of M. fructigena on Kieffer pears at Beltsville.

A study of uredial development of Phakopsora pachyrhizi, causal organism of rust of soybeans was completed.

Nearly all details in the life cycle of Zopfia rhizophila, a parasite of asparagus roots, were determined. Two previously undescribed genera of leaf-parasitic fungi with unusual significance in the classification of Basidiomycetes were found to develop reproductive sori similar to those of the rust fungi. One species, Proliferobasidium heliconiae, from Dominica, has an unusual form of basidial repetition found in very few other Basidiomycetes. The other fungus, Ceraceosorus bombacis, causes an apparently serious leaf disease of Bombax ceiba, which is a commercially important soft hardwood tree in India.

More than 9,000 records have been assembled for the preparation of a bibliography and host-pathogens index of fungi potentially useful for biological control of deleterious aquatic weeds and algae. Monographic work on black mildew fungi at present is concentrated on the Dimeriella species-complex and on species usually referred to the genus Microcallis. Preliminary results show that most of the species of Microcallis should be distributed in the families Chaetothyriaceae and Micropeltaceae. The study also has shown that certain species of Dimeriella are not as host-specific as earlier taxonomists had assumed.

As a basis for comparison with American species, European mushrooms were collected during six months of study sponsored primarily by the National Academy of Sciences. Information from field studies in Germany, Switzerland, and Austria was particularly significant in relation to present research projects on mushroom taxonomy and ecology. Collections of the Gyromitra gigas - G. fastigiata complex were obtained in the forests east of Vienna. Species concepts also were clarified by specimens obtained from classical old-world mushroom collection sites in Hungary. Specimens of Agaricus bernardii, obtained there, should help to resolve the taxonomy of certain species in the Agaricus edulis group of North America. Similarly, a collection of Amanita strobiliformis was obtained for comparison with specimens erroneously referred to that species in the Southeastern United States.

In the Beltsville and metropolitan Washington areas an extensive survey of lawn fungi was undertaken. During the summer and autumn months, 300 collections of lawn mushrooms were photographed and collected for study. Field notes and subsequent observations in the laboratory will be used for preparation of a manual of lawn fungi.

Preparation of a manual of poisonous mushrooms in the United States is approaching completion. The manuscript constitutes the basis for a book on mushroom identification, medical aspects of mushroom poisoning, and the chemistry of mushroom toxins. Principal toxins under discussion are the amatoxins, gyromitrin, psilocybin, ibotenic acid, and muscarine.

In a study of cellulose decomposing fungi, data from growth-rate and temperature-range studies of 64 Chaetomium isolates showed that many species are capable of growing at relatively high temperatures prevalent in compost heaps and similar substrates in which metabolic activities of microorganisms raise the temperature. Only the isolates of C. thermophile and C. virginicum are true thermophiles, with growth at temperatures up to 55°C (131°F). Isolates of 24 other species grew as either microthermophiles or thermotolerant organisms at temperatures reaching 40-50°C (104-112°F). Growth rates of thermophilic isolates at 45-50°C far exceeded the maximum rates achieved at any temperature by nonthermophilic isolates.

Work with thermophilic and thermotolerant fungi has been extended to include studies of fungal populations in sludge composts, particularly with reference to the presence of plant and human pathogens. Preliminary study confirms the presence of proven or potential human pathogens such as Aspergillus fumigatus and thermophilic Mucor spp. The incidence of plant pathogens is low.

Research on cellulose decomposing fungi also centered on the corticioid genera Hyphoderma, Hyphodontia, and Vararia. Basidiocarp morphology and the growth characteristics of cultures were determined for 10 species in Hyphoderma and Hyphodontia. All basidiocarp collections were from either Mississippi or Arkansas, and all represent new records from those states. Many species of Vararia diverge considerably from one another in their morphology and growth characteristics, an indication that the genus may not be homogeneous.

Investigations of life history and cytology in the Pyrenomycetes continue to reveal developmental patterns significant in taxonomic classification. Recently completed work on Sordaria humana made possible the first recorded explanation of ascocarp-wall expansion in a Pyrenomycete. In other studies of Ascomycetes a new truffle species was discovered near Hagerstown, Maryland, and described as Tuber spinoreticulatum. Several hundred collections of Myxomycetes were identified and many were added to the herbarium of the National Fungus Collections. Work on records of the New Taxa Index revealed that the lichen genus name Reticularia Baumg. has nomenclatural priority over the Myxomycete genus name Reticularia Bull.



The addition of 3,439 collections to the fungus herbarium brought the total in the National Fungus Collections to 802,638. This is the only fungus herbarium in the world with more than 800,000 collections. During the year, loans of 534 collections were made for research studies by scientists in the United States and abroad. Work continued on the records of type collections in the National Fungus Collections, with particular attention to types of the genus Polyporus. Direct outside service work of identification, specimen loans, and information occupied approximately 20 percent of total staff working hours.

Plant Virology Laboratory (Davis, Diener, Hadidi, Kaper, Owens, Schneider, Steere): As part of our physico-chemical studies of viruses we have completed first characterization and identification of the presence of a strain of peanut stunt virus from Europe. A special replicating component of cucumber mosaic virus which may be a satellite or defective RNA has been identified as RNA # 5.

Studies of satellite viruses in cooperation with scientists at the Rockefeller University, New York City, have shown that the RNA of the satellite of tobacco ringspot virus (S-TRSV) is a molecule of low complexity consistent with its estimated molecular weight of about 90,000 daltons. A procedure has been developed for the improved purification of double-stranded RNAs that are found in tissue infected with S-TRSV. A large portion of the double-stranded S-TRSV RNAs elute ahead of conventional double-stranded RNAs in a CF-11 cellulose column which is generally used by many scientists for the separation of double-stranded and single-stranded RNAs.

A large number of components (8 or more) are present in the double-stranded RNA population. Only a small part of the population approximates the size one would expect for the replicative form of S-TRSV (180,000 daltons). The bulk of the population is composed of components that are 2 to 20X the expected mass. Melting of these large complexes and bioassays revealed that these unexpectedly large complexes are composed of single-stranded S-TRSV RNAs of the same small size and biological activity as those known to occur within S-TRSV virions, and large negative strands.

**Viroids:** DNA sequences complementary to potato spindle tuber viroid (PSTV) have been detected in uninfected hosts of PSTV. This is the first known RNA pathogen of higher plants which possesses complementarity of its host DNA. Our findings suggest that PSTV originated from cellular genetic information and that its replication is DNA-directed.

Complementary DNA (cDNA) copies of PSTV have been synthesized in vitro using DNA polymerase I of Escherichia coli. The size of cDNA is about half that of PSTV. The specificity of cDNA copies of PSTV was tested by its hybridization to several RNA species; maximum hybrid yield was obtained when cDNA was hybridized with PSTV indicating some degree of specificity.

PSTV has been used as a template for RNA synthesis using a bacteriophage. Heterogeneous mixtures of products were obtained. The apparent molecular weight of the largest product, however, approached that of PSTV.

The base composition of purified PSTV was determined by a method involving enzymatic digestion to nucleosides, oxidation with periodate, and introduction of radioactive label by reduction of the resulting dialdehydes by  $^3\text{H}$ -borohydride. The base composition in percent is: G= 28.9; C= 28.3; A= 21.7; and U= 20.9.

Spiroplasmas, mycoplasmas, and other unusual procaryotes: During the past 5 years, an entirely new type of pathogen--a helical, wall-free, motile procaryote--was discovered in corn stunt disease and was recognized as the first representative of a new group of pathogens of plants, insects, and mammals. In the past year, the corn stunt spiroplasma DNA-base composition, other physiological properties, morphology and translational motility in vitro, and growth in simplified media were characterized. A new Spirillum-like nitrogen-fixing bacterium was found in association with roots of Sudangrass hybrid and sugarcane.

Electron microscopy: Additional electron micrographs of freeze-fractured cells have revealed more information regarding the three-dimensional structure of tobacco mosaic virus crystals. Crystals of the U-5 strain are found to be of at least two types which are both distinct from those observed for the common strain. The freeze-etch procedure has been used to explore the ultrastructure of acrylamide gels revealing both the larger mycells and the very fine details of the mycell faces. A resistance monitor has been developed which permits the evaporation of desired film thickness of platinum and carbon and which should drastically increase the reliability of preshadowed carbon replicas.

Soilborne Diseases Laboratory (Adams, Ayers, Lewis, Lumsden, Papavizas):

Soil temperature and moisture content were found to be two of the most important factors affecting survival ability of sclerotia of Macrophomina phaseolina, the soilborne fungus that causes charcoal rot of many economic crops. The following moisture-temperature combinations were detrimental to sclerotial survival in soil: Low soil moisture and high temperature (25-35°C); high soil moisture and low temperature (-5 and 5°C); high soil moisture and cycles of freezing and thawing.

Hyphochytrium catenoides, a mycoparasite that destructively invades oospores of plant pathogenic Pythium and Aphanomyces spp., was isolated from 6 of 17 soils from different locations. The mycoparasite produced motile zoospores that accumulated about the oospores of susceptible plant pathogens, invaded the oospores, and then continued the cyclic production of new infective units in water and in moist soil.

Initially dormant oospores of Aphanomyces euteiches were induced to germinate gradually by incubation in water, on agar impregnated with soil, and in moist soil. A microscopically-identifiable pregermination (activated) stage of the oospores was recognized.

Oospores of Pythium myriotylum, the bean blight pathogen, survived only for a short time in naturally infected bean debris buried in soil. After 6 months no viable propagules were detectable. Further examination of the debris revealed the presence of various fungi with the ability to invade P. myriotylum oospores. Studies on P. ultimum, a second bean pathogen, indicated the presence of a self-inhibitor in spent cultures of the fungus that prevented germination of oospores. Oospores could be washed free of the inhibitor to allow breaking of dormancy and germination.

The physiology of Sclerotinia sclerotiorum was studied in relation to pathogenicity and host plant resistance. Infection hyphae, necessary for successful host plant infection, were produced in culture. Extracts obtained from susceptible host plant tissue induced production of infection hyphae on the surface of cellophane. A method of germination of sclerotia of S. sclerotiorum was described for the first time. This method of germination was shown to cause disease directly without the need of an organic food base.

In field tests in New Jersey it was found that in fall-planted onions there is usually a great deal of infection of onions by Sclerotium cepivorum in October, November, and December which causes a decline in plant stand. Additional infection occurs in spring and continues until harvest in April or May with no apparent affect on plant stand.

Maintaining soil infested with the onion white rot fungus continuously moist for 20 weeks before planting onions reduced the disease considerably. Exposure of sclerotia to high relative humidity in vitro resulted in complete loss of their germinability. The highest amount of white rot was observed on onion seedlings transplanted to infested soil kept air-dried for 20 weeks before transplanting and seedlings.

Soil texture, as well as biological and environmental factors, influenced Rhizoctonia solani survival in soil. There was less pathogen saprophytic activity in a sandy loam to which clays were added than in sandy loam to which sand was added. However, a R. solani suppressive silty clay loam was not made less suppressive by addition of sand to it. This indicated that biological factors are more important than chemical ones in soil. Under field conditions, two R. solani isolates survived poorly regardless of soil type indicating the importance of environmental influence on survivability.



Herbicides, used at recommended rates, did not influence overall microbial activity in two nonamended or amended soils. Soil pH, moisture, fertilizer, or delayed amendment addition did not influence herbicide activity. Specific microbial populations were affected. Some herbicides almost eliminated soil algae, whereas others significantly increased the activity of S-oxidizing thiobacilli. A study on the effect of herbicides on soybean development in the greenhouse indicated that herbicides adversely affected either plant weight, height, or nondulation.

Bozeman, MT (Scharen): A method was developed that permits precise evaluation of Septoria symptoms on wheat seedlings, and accurate comparisons of resistance levels in different lines and cultivars of wheat. Quantitative inoculation of S. nodorum, with post-inoculation dew periods that varied from 24 to 96 hr. elicited different responses on spring and winter wheats permitting their categorization as to disease response.

Winter wheats as a group are more resistant to infection with S. nodorum than are spring wheats. The inheritance of resistance to S. nodorum was different in progeny of several crosses, giving evidence of partial dominance, additive effects, and transgressive segregation. Fourteen cultures of S. nodorum were studied as to their interactions with 10 diverse cultivars of wheat. The cultures varied in virulence and aggressiveness, but no culture-cultivar interactions were found that would suggest biotypes or physiological races of the pathogen.

dwarf

Brookings, SD (Jensen): Oat blue/virus (OBDV) has been brought into culture, but the level of transmission by the vector Macrostiles fascifrons is very low. Endria inimica transmits wheat striate mosaic virus (WSMV) with good efficiency, but the insect population increases slowly. Ethlene production by cereals is much lower than with broad leafed and other experimental plants and seems to be reduced by as much as 50% by barley yellow dwarf virus (BYDV) infection. This result is quite different from other virus infections and is perhaps related to virus production rather than growth. Significant closure of stomates has been observed as early as 2 days after inoculation with BYDV.

Electron microscopy of BYDV-infected barley meristem tissue has revealed the presence of virus particles in xylem tissue, and more severe cytological effects have been seen in the zone of elongation and the zone of maturation than in mature tissues. Reproductive meristem did not contain virus particles.

Several hundred collections of forage and range grasses were made from selected sites in South Dakota and from the ARS station at Mandan, ND. Infectivity tests for the presence of mechanically transmissible viruses revealed only brome mosaic from field collections near Brookings and the SDSU nursery plots. No viruses were recovered from the Mandan, ND, or other South Dakota samples. Limited recovery trials for the presence of insect-transmitted viruses have not yet identified vector specific viruses. A limited outbreak of wheat streak mosaic virus in central South Dakota was traced to virus-infected and mite-infected cheat grass.

Frederick, MD (Bonde, Bromfield, Damsteegt, Emge, French, Graham, Irish Kingsolver, Latterell, Melching, Peet, Schmitt): A mutant strain of Cercospora zeae-maydis was isolated from a Missouri culture that forms only the Asteromella (male) stage in culture. Histological studies yielded excellent stained sections of spermatogonia. C. zeae-maydis specimens were collected for the first time in Maryland (Washington County). Successful infection of corn was obtained in field plots inoculated in mid-season, but secondary development was inhibited due to leaf coverage by Puccinia polysora. Anthracnose (Colletotrichum graminicola) again was observed to be a far more serious disease than in the past, apparently because of the early buildup of inoculum on debris remaining in the fields as a result of no-till culture practices.

Two leaf-spotting pathogens of corn found to be serious in parts of Central and South America were identified as Diplodia macrospora and Leptosphaerulina sp. The former has been known in the southern U.S., but primarily as a stalk- and cob-rotting fungus. Artificial inoculations have induced severe leaf blight as well as stalk rot. The species of Leptosphaerulina has been tentatively identified as L. australis, and may be synonymous with Pleosphaerulina zeicola, which was described from Illinois in 1930.

A severe strain of Helminthosporium maydis (Race 0) isolated from specimens collected from Warsaw, Virginia and Wye, Maryland was comparable in virulence to the severe Florida strain when inoculated onto 12 test varieties.

Corn, johnsongrass, sorghum, and foxtail were collected during surveys made to determine the presence and severity of viruses affecting corn in Maryland. Maize dwarf mosaic virus (MDMV) was present in 14 countries; Maize chlorotic dwarf virus (MCDV) in 9. MDMV was the more prevalent of the two viruses. Every site with infected corn invariably also had johnsongrass in close proximity. This suggests that the viruses overwinter in the perennial johnsongrass.

Six domestic migratory species of leafhoppers (Exitianus exitiosus, Macrosteltes fascifrons, Dalbalus elematis, D. maidis, Endria enemica, Graminella nigrifrons) and the planthopper, Sogatodes orizicola, failed to transmit the African Maize Streak Virus when they were injected with the virus and allowed to feed on healthy XL45 corn seedlings. All of 85 individuals of Cicadulina mbila did transmit the virus when injected and allowed to feed as described above.

The reaction of soybean varieties Cutler and Kent grown in greenhouse soil beds and in field plots were compared following inoculation in the 0,1 growth stage with 3 viruses. The viruses used singly and in all possible combinations were soybean mosaic virus (SMV), bean pod mottle virus (BPMV), and tobacco ringspot virus (TRSV). Virus combinations with BPMV and TRSV produced the greatest losses but spread of TRSV and SMV from clover, narrowleaf plantain, and other weeds, confounded results as did grazing by rabbits. SMV was the most commonly found contaminant virus in the field plots.



A culture of Sclerospora sacchari from Taiwan and one of S. philippinensis from The Philippines were established from living material collected and transported under quarantine permit. Corn genotypes XL43 and 3369A are good donor hosts for these isolates. A dew period of 7-8 h at 23-24 C following 13 h of light (ca. 2000 fc from halide lights) induces sporulation.

Conidial dosages less than those indicated in the literature may cause severe infection by S. sorghi. Seventy five percent of the plants of Tx412 sorghum receiving an inoculum dosage of 3875 conidia per plant became systemically infected and 90% became infected when this dosage was doubled. Good systemic infection of Tx412 has occurred when plants were inoculated as late as the 5-7 leaf stage with conidial dosages of 200,000 conidia/ml at 0.5 ml/plant.

Two races of Phakopsora pachyrhizi, causal agent of soybean rust, have been distinguished on the basis of differential reaction of soybean genotypes. In those sets inoculated with a rust culture from Taiwan, all genotypes produced susceptible reactions. In those sets inoculated with a culture from Australia or with one from India, only Ogden and Wayne produced susceptible type reactions; the other four accessions were immune, i.e., no macroscopic evidence of lesions. Three genotypes from Taiwan, reputed to have field resistance, Wayne, and Dare were inoculated with rust culture Taiwan-72-1 and compared. No significant differences in rust behavior were noted among the 5 genotypes.

P. pachyrhizi has been reported on cowpea in Africa. The pathogenicity of this material to soybeans is currently unknown. Investigation of the reaction of cowpea varieties to P. pachyrhizi from soybean has been initiated at PDRL with cowpeas provided by J. P. Meiners. Cowpea cultivar Blackeye #5 has been challenged with cultures Taiwan-72-1 and India-73-1. The cultivar reacted similarly to both rust cultures. Although Blackeye #5 became infected, it is not a congenial host for the two cultures of the soybean rust fungus tested because of delayed and restricted sporulation. It could, however, serve as a potential source of inoculum of soybean rust.

Soybean plants (Wayne) grown in the greenhouse in 4-inch pots under natural daylight only from 2-5-75 through 5-27-75 produced 25% fewer pods, 20% fewer beans, and 40% less dry weight of beans than did plants grown under natural daylight plus 12 hours of supplementary light per day from General Electric Metalarc lamps. Plants receiving natural plus supplementary light had more leaf area per leaf, were shorter and thicker-stemmed, and more yellow-green in color than the natural daylight plants.



Soybeans (Wayne) grown at simulated field spacing in large planting boxes in the greenhouse were inoculated with uredospores of Phakopsora pachyrhizi at the 5th leaf stage and exposed to different periods of dew. Yields ranged from 45 bu/a (control, no rust) to 10.5 bu/a (dew every 3 days).

Twelve corn inbred lines and five commercial hybrids were tested in the greenhouse for their reaction to southern corn rust, caused by Puccinia polysora. All the commercial hybrids were rated highly susceptible. Most of the inbreds showed a fully susceptible reaction, but three (B73, WI53R, and Mo 17) had lower terminal severities of rust than the commercial hybrids. Three inbreds were resistant to rust throughout their development; these were VA 26, A619, and B1138T sel.

Uredospores of Physopella zeae, the cause of tropical corn rust, germinated in dew on leaves of DeKalb XL-43 corn seedlings within 1-2 hours at 20 C in the dark. Appressoria formed within 5 hours, usually over anticlinal walls of epidermal cells. Direct penetration occurred within 16 hours, at which time ellipsoidal primary hyphae were observed within epidermal cells. Secondary hyphae grew from primary hyphae within 24 hours; at 40 hours they had elongated and branched but were still confined to the initially penetrated cells. They penetrated the interior epidermal cell walls and grew into adjacent epidermal and mesophyll cells. Six days after inoculation, pustules erupted through the epidermis.

The percentage germination of oospores of Sclerospora sorghi exposed to ultraviolet light or to furfural at 100 ppm was slightly higher than that of untreated control oospores. Contamination of oospores with other microorganisms continues to confound experimental results.

A crude distillate of uredospores of Phakopsora pachyrhizi stimulated uredospore germination of Puccinia graminis tritici. Uredospore germination of Phakopsora pachyrhizi was not stimulated by several chemicals that are effective germination stimulators for certain other rust species.

Uredospore germination of Puccinia graminis tritici and Puccinia coronata avenae was significantly stimulated by exposure to nonanal vapor for periods as brief as 20 seconds. A comparable response of uredospores of Uromyces phaseoli was observed following exposure to vapor of beta ionone.

Uredospores of Puccinia graminis tritici were stimulated by a variety of aldehydes, alcohols, and ketones, but among these classes of compound, only certain methyl ketones stimulated uredospore germination of Uromyces phaseoli. This points out important biochemical differences in response of these two rust species.

Conidia of Penicillium digitatum and Penicillium italicum responded with enhanced germination to nonanal, citral, and orange oil. Spores of Diplodia macrospora and Chuppia venezuelensis were tested for stimulatory response to several compounds with inconclusive results.

An electronic leaf surface wetness probe has been incorporated into a conventional hygrothermograph unit; this provides a permanent record of leaf wetness frequency and intensity on the same 7-day chart with the temperature and relative humidity parameters.

Ithaca, NY (Rochow): In cooperative studies with Dr. Rene Scalla, both the RPV and MAV isolates of barley yellow dwarf virus (BYDV) were found to contain one major protein subunit. The tentative molecular weight for the MAV subunit is 23,700 daltons, that of RPV is 24,200. In work on development of serological procedures, we processed more than 175 kg of original oat tissue to make purified preparations of 6 different inocula for injection into rabbits to produce virus-specific antisera.

Studies of the importance of the age of virus source leaves in vector specificity of BYDV were completed. Direct use of electron microscopy to visualize BYDV within aphid vectors was found to be impractical. More than 100 virus isolates transmitted from field-collected samples during the year all proved to be similar to one of the 5 variants of BYDV previously encountered.

Tests of various mixed infections with 4 BYDV isolates similar to MAV, and another 4 isolates similar to RPV showed that dependent transmission of MAV-like isolates from mixed infections by R. padi occurred readily from all double infections. These results support the possibility that dependent virus transmission could be important in natural spread of virus. Attempts to alter vector specificity of RPV or MAV by injecting treated virus into both R. padi and M. avenae were unsuccessful.

Madison, WI (Durbin, Helgeson, Kemp, Upper): Tentoxin, a cyclic tetrapeptide produced by Alternaria tenuis, induced chlorosis in certain plant species. It inactivated photophosphorylation and coupling factor 1 (CF<sub>1</sub>) ATPase in lettuce, a sensitive species. In radish, an insensitive species, 20 times more tentoxin was required for 50% inhibition of photophosphorylation.

Sensitivity of photophosphorylation to tentoxin was correlated with chlorosis sensitivity in 6 other species examined. A survey of species in 14 plant families involving seed germination tests has shown that all members of Cruciferae are insensitive; varying numbers of Solanaceae, Convolvulaceae, Leguminosae, and Graminae are insensitive; and all species within the other families are sensitive. Both sensitive and insensitive Nicotiana spp. were identified and work is in progress to use them for a genetical analysis of sensitivity.

We have not been able to detect Agrobacterium tumefaciens DNA in sunflower crown gall cells. The discovery of a plasmid in A. tumefaciens that represents only 5% of the total DNA has reopened the possibility of gene integration. We have developed techniques to purify plasmid DNA and reanneal it with crown gall DNA. Preliminary experiments suggest that crown gall tissue does not contain bacterial genes. However, there is still no direct evidence that bacterial genes are integrated into crown gall cells.

The strongest indirect evidence for gene integration is the finding that the bacterial strain used to incite tumors, rather than the plant species, determines whether the unusual amino acid octopine or nopaline is present in the tumors. We developed a sensitive assay for detecting these amino acids and concluded that neither octopine nor nopaline are present in normal plant tissues, but that they are always present in crown gall tissue. The enzyme responsible for production of the unusual amino acid in the crown gall tissue is being compared to the bacterial enzyme. If the two enzymes are identical, then gene transfer probably occurred.

Physical methods for determining the base composition for bacterial, fungal, and most animal DNA have been well established. However, plant DNA, because of the presence of significant amounts of 5-methyldeoxycytidine, has an altered buoyant density making the established equations invalid. The base composition of a number of plant species was determined chromatographically and the values agreed with determinations based on physical parameters.

Using uptake and incorporation data, absolute rates of RNA synthesis were calculated for exponentially growing tobacco callus tissues. Rates of RNA accumulation were 45% lower than the rate of synthesis suggesting a significant rate of RNA turnover. Since ribosomal RNA was reported not to turn over in exponentially growing tissue, it was isolated by sucrose gradient centrifugation and its rate of synthesis determined to be very similar to that of the rate of accumulation of RNA.

The cyclic hydroxamic acid 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) is the most abundant of a number of related hydroxamates in corn, and is the major factor in corn inhibitory to non-corn soft-rotting Erwinia spp. Corn lines lacking DIMBOA are not susceptible to non-corn soft-rotting bacteria. Thus, DIMBOA may be involved in resistance of corn to these bacteria, but it cannot be solely responsible for resistance in the host-pathogen systems tried thus far.

Biochemical mutants of E. chrysanthemi var. zeae, the corn leaf and stalk-rotting organism, have been made and tested for virulence. Attempts are under way to make a DIMBOA-sensitive mutant. Improved inoculation procedures have been developed to measure quantitatively the resistance (susceptibility) of corn to soft-rotting bacteria.



Although genetically marked ascospores of Venturia inaequalis can be recovered from field leaves to which marked clones were applied in the fall, the frequency of matings of applied lines with endogenous V. inaequalis is judged too low for this to be a feasible means of controlling apple scab disease. Time of application in the fall, weather conditions at the time of inoculation, and methods of preparation of the inoculum have all been examined in attempts to increase the extent to which exogenous lines will mate with established lines. All have been unsuccessful to date.

In cooperative work we have shown that the single dominant genetic factor which confers disease resistance to intact tobacco plants is expressed in tobacco pith callus tissues. We have found that the cytokinin concentration is critical for obtaining disease resistance in tissue cultures. Callus tissues from resistant plants support little fungal growth when supplied with 1  $\mu$ M kinetin. In contrast, tissues from susceptible plants are heavily colonized. When kinetin concentrations are progressively increased from 1 to 10  $\mu$ M, colonization of tissues from resistant plants is progressively increased. At 10  $\mu$ M, copious fungal growth, comparable to that on tissue from susceptible plants, is noted. Thus, within a single genotype, resistance can be obviated or expressed depending on defined growth conditions. This development will permit controlled experiments on disease resistance within which the only variables will be tissue culture addenda and the control of gene expression with the same, clonally maintained, plant.

Substantial evidence has been accumulated to implicate bacterial ice nuclei as incitants of warm temperature (>-5C) frost injury to plants. Plant leaves (many species) supercool in the absence of exogenous ice nuclei; no warm temperature frost injury occurs. Addition of ice nucleation active (INA) bacteria to growth chamber-grown plants prevents supercooling; frost damage occurs. All frost sensitive plants so far examined (many species) have INA bacteria as normal components of their epiphytic flora; natural INA bacterial populations are adequate, on the basis of laboratory experiments, to prevent supercooling of leaves. Treatment of field leaves with streptomycin decreased both the frost sensitivity of leaves, and the numbers of INA bacteria on them.

We have demonstrated that the gene that confers resistance to Phytophthora parasitica var. nicotianae in intact tobacco plants is also expressed in tissue culture. Rooted cuttings and pith callus tissues were compared directly for their resistance to the fungus. In each case, plants that yielded susceptible cuttings yielded only susceptible callus, and plants that yielded resistant cuttings yielded resistant callus. To our knowledge this is the first rigorous demonstration that a specific factor for disease resistance is expressed in both intact plants and tissue cultures. Extracts of uninoculated tissue cultures are stimulatory to fungal growth, but those of inoculated tissue are inhibitory.

St. Paul, MN (Bushnell, McVey, Roelfs, Rothman, Rowell): Time-lapse studies in host cells invaded by obligate parasites were completed and showed that most of the papilla structure is deposited in about 30 minutes. The data allow calculation of the growth rates of papilla thickness which, in turn, relate to possible mechanisms of deposition at the ultrastructural level.

A wide range of inappropriate host plants was examined cytologically after inoculation with two powdery mildew fungi. Resistance of these hosts was associated most frequently with failure of the fungus to develop normal infection structures or to penetrate host cell walls, although papilla deposition and hypersensitive cell death occurred in some cases. The results implicate substances and structures on plant surfaces in the general resistance of the inappropriate hosts.

A serial dilution and seeding technique was developed to place series of decreasing quantities of rust uredospores aseptically on artificial media. This technique showed that a minimum threshold amount of 0.2-0.5 mg of spores was required to initiate growth of a test isolate in single dishes, and shows promise as a bioassay procedure for possible growth-promoting substances from spores or other sources.

Nine cultures of Puccinia graminis which had been serially subcultured for several years on artificial media were examined for characteristics of cells and nuclei. Colonies were either fluffy, with long narrow cells, or compact, with short wide cells. Both types usually had two nuclei per cells. The fluffy colonies had nuclei twice as large as those of the compact colonies, an indication that the degree of ploidy had doubled in the fluffy types during their subculturing histories.

Specific genes for resistance in commercial cultivars govern, in part, the prevalence and distribution of rust races and thus the seasonal epidemic potential. The avirulence-virulence complement of genes is the only distinctive marker available to follow the pathogen spread. This characteristic is defined by determining the infection type on host lines with individual specific genes for resistance. Adequate seed was prepared to study pathogen populations of wheat stem rust on host lines with the specific genes for resistance Sr5, 6 7b, 8, 9a, 9b, 9d, 9e, 9f, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, and the unnumbered genes Tt-1, Tt-2, Wst, Kota 2, Tmp 64, and dp-2. The avirulence-virulence characteristics of over 300 cultures of stem rust were determined for these resistances.

Host lines with other specific genes for resistance are in preparation for adding to this set of rust culture identification. Seed of lines for Sr7a and 29 are being increased. Lines were selected for unnumbered genes SrTc from Thatcher and Sr'X' from Marquis from crosses of these lines with Baart and Prelude. Other unnumbered genes were found: SrLC in Little Club and Baart, SrPl in Peliss, and SrPt in Peterson M.L. 68-14.

Adequate seed was prepared to study pathogen populations of oat stem rust for host lines with the specific genes for resistance Pg-1, 2, 3, 8, 9, and 13. The avirulence-virulence characteristics of 50 cultures of oat stem rust were determined for these resistances.

The nature of the resistance to P. graminis tritici designated as the 'T' gene in the barley cultivar Larker was evaluated by testing progeny from a cross with Hiproly (no seedling resistance at 75 F) with a single rust culture. The F<sub>2</sub> population segregated for both numbers of infections and infection type into 6 classes of reactions.

Fifty-nine uredial collections were received from 11 of the locations growing the UORN. Only races 31 and 61 were identified from the collections received within the U.S.A. from naturally occurring stem rust. Seven races were identified from Appleton, Ontario, an area where Berberis vulgaris, the alternate host, grows freely.

Seedlings of all entries in the IORN were tested with six races of oat stem rust to obtain the probable genotype of each entry. Genes Pg-1, Pg-2, and Pg-4 either alone or in combinations were most frequently identified, and pg-9, pg-11, and pg-12 were also encountered.

The diversity of the crown rust races present in the buckthorn plots were determined through aecial and uredial collections made during the growing season. Of the 14 physiologic races identified, eight were common to both the buckthorn aecia and oat uredial collections, two only from aecia, and four only from uredia.

The identification of genes for resistance in F<sub>3</sub> populations of the susceptible Baart wheat with Waldron by three isolates of stem rust (TNM, HNL, and QFB) indicated an unknown dominant gene giving IT 2, an unknown recessive gene also giving IT 2, a dominant gene giving IT; (probably Sr11), and a dominant gene giving IT 0 (probably Sr5) in a position of the Waldron population. Crosses were made and advanced to the BC/F<sub>2</sub> generation between monogenic lines Sr11, Sr5, and lines giving IT; and IT 0, respectively. A cross was made between lines with the dominant gene giving IT 2 and monogenic line Sr13 and advanced to the BC/F<sub>2</sub>.

The identification of genes for resistance in F<sub>3</sub> populations of Baart/Chris with stem rust isolates RHR, TNM, HNL, and QFB indicated genetic ratios of 3 dominant; 1 recessive; 1 dominant and 1 recessive; 2 dominant and 1 recessive, respectively.



CROP DISEASE CONTROL (NON-COMMODITY)

T02: Develop systems for economic control of plant diseases and nematodes with maximum beneficial effects on yield and quality, and minimum undesirable effects on the environment and public health.

Beltsville, MD

Soilborne Diseases Laboratory (Adams, Ayers, Lewis, Lumsden, Papavizas):

The organic solvent infusion method, a new method to treat seeds with minimal amounts of fungicides to control soilborne plant pathogens, has been developed. This was the first time attempts were made to control a soilborne plant disease, Phytophthora root rot and damping-off of soybean, with a systemic fungicide applied to the seed in small amounts with the acetone infusion method. Soybean seed soaked in acetone solutions of pyroxychlor, a new systemic fungicide, for up to 30 minutes showed no detrimental effects on the seedlings; and the treatment provided dramatic control of Phytophthora damping-off and root rot. Pyroxychlor in acetone did not affect nodulation and did not cause phytotoxic symptoms in various soybean cultivars. Also, bean, cotton, and pea seeds germinated well (over 90% of control) after soaking up to 24 hr in acetone, dichloromethane, or alcohol. The present successful attempts may open new possibilities for control of soilborne plant pathogens and nematodes with fungicides or nematicides infused into the seed before planting.

Of five commercially available calcium salts, hydrated lime, rock phosphate, and limestone significantly reduced Aphanomyces root rot of peas in a Beltsville field. Plant stand was high in nonamended and amended soils. Rock phosphate significantly increased pod weight and both rock phosphate and hydrated lime increased plant root wet weight. Several of these calcium salts also consistently reduced black root of sugarbeets in the greenhouse caused by A. cochlidioides. Gypsum, hydrated lime, and calcium oxide were effective whereas rock phosphate significantly increased disease over the control.

The inoculum density of Sclerotinia sclerotiorum in numerous New Jersey lettuce fields was found to be too low to be correlated with subsequent disease development. Field tests for the control of lettuce drop were inconclusive because of the limited amount of disease. Because of the unusually wet summer, field evaluation of a cultural-biological control measure for lettuce drop was also inconclusive. Control of onion white rot by experimental chemicals in the field was not as good as that found in previous years.

Several double and triple fungicidal combinations applied to bean seed improved stand and reduced root rot caused by Fusarium, Rhizoctonia, and Thielaviopsis in the states of New York and New Jersey. Of the combinations tested, carboxin + captafol, carboxin + benomyl, carboxin + Terraclor Super X, captafol + benomyl, captafol + Banrot, and carboxin + thiophanate

methyl + chloroneb were effective against all three pathogens. This work was done in cooperation with the Geneva Agricultural Experiment Station and the Rutgers Research and Development Center at Centerton.

The preemergence herbicides DCPA, EPTC, bensulide, diuron, and trifluralin plus diuron increased black root rot of cotton caused by Thielaviopsis basicola and reduced cotton stand. Several herbicides were screened for interactions with disease incidence in cotton and bean caused by T. basicola and Rhizoctonia solani, respectively. Root rot incidence in beans was not increased by the herbicides.

Bozeman, MT (Scharen): Selections of wheat were made for resistance to a natural epidemic of leaf spot diseases at Sidney, MT in 1975. In addition to the fungus pathogens that are seen every year, the bacteria Pseudomonas syringae and Xanthomonas translucens did great damage in 1975. Differences in response to the diseases were found among our own selected materials; the ARS Septoria nursery coordinated from Bozeman, MT; the Septoria nursery of CIMMYT; and from the winter and spring variety development programs carried out in Montana. Lines exhibiting resistance were selected for further study.

Several F<sub>7</sub> progeny of crosses made in 1971 exhibit high levels of resistance to Septoria nodorum and Septoria tritici in seedling tests, as well as good performance under natural epidemic conditions in the field. Progress to the F<sub>4</sub> generation has been made in accumulating resistance in cultivars that are desirable for agronomic, yield, and quality characteristics.

Interest has increased in the ARS International Septoria Nursery, with new entries from foreign cooperators, and additional domestic and foreign participants. Our selections look particularly good in North Africa, Turkey and Israel.

Frederick, MD (Bonde, Bromfield, Damsteegt, Emge, French, Irish, Kingsolver, Latterell, Melching, Peet, Schmitt): A naturally occurring epidemic of maize dwarf mosaic and maize chlorotic dwarf was studied in a sweetcorn field in Harford County, Maryland. Scattered clumps of infected johnsongrass served as sources of inoculum. Rate, direction, and extent of spread of virus symptoms in the corn was determined for each discrete inoculum source.

More than 125 commercially important or promising new corn hybrids from 6 companies were very susceptible to maize streak virus (MSV). No resistance was found in the inbred lines which include that bulk of U.S. commercial germplasm. Thirty-nine perennial grass species common to the southern and northern corn belts were tested for virus reaction and suitability for completion of the life cycle of Cicadulina mbila. Fourteen of the 39 species are hosts for the virus; 3 are quite suitable for oviposition by the insect vector.

Corn genotypes 33-16 and R177 have consistently shown good resistance to S. sorghi in all screening tests at PDRL. In comparative tests they have shown resistance as good as, or better, than that of other U.S. lines tested to date. Of the foreign genotypes tested to S. sorghi at PDRL, Tainan DMR Composite 1, 2, 3, and Mit x Cuba Gr1 showed good resistance when spray-inoculated with conidial suspensions. Among 50 Iowa corn lines supplied by Dr. Eberhardt, BS8(SD) C3 #016, 019, 028, and 036 showed good resistance to S. sorghi. Gene Scott's diallel crosses /Tx601 x Mp337 Fla 7475 : 109 x 110/ and Mp337 x SC359 Fla 7475 : 119 x 120/ showed fair resistance to S. sorghi. Of 52 sweet sorghum genotypes screened for Dr. Stanley King, 11 showed fair resistance to S. sorghi.

Inoculations of field-grown corn (Pioneer 3369A) with uredospores of Puccinia polysora (Maryland isolate) were made in 2 x 2 m foci at the center of 18 x 18 m plots at 20, 31, 41, or 50 days after crop emergence. At 75 days after emergence, when the physiological processes involved in filling the ear should have begun, rust severity was 30 times greater on plants inoculated 20 days after emergence than on those inoculated 30 days later. Compared with fungicide-sprayed Maneb (1.5 lb active/100 gal) control plot yields of 168 bu/acre, the 21, 31, 41 and 50 day plots produced yields corresponding to 95, 91, 115, and 119 bu/acre, respectively, in the focus areas.

Selected areas within a 4-acre planting of corn (Pioneer 3369A) were sprayed with maneb at 34, 46, 68, and 77 days after crop emergence. Artificial inoculation of other areas within the planting with uredospores of Puccinia polysora resulted in rust buildup and production of secondary inoculum throughout the field. At maturity, plants immediately surrounding the sprayed areas had an average of  $8 \times 10^4$  pustules/plant, whereas the sprayed plants had an average of  $4 \times 10^3$ . Within the sprayed areas, yields were an average of 28 bu/acre more than in the immediately adjacent areas.

The following germplasm material has been increased as a service to plant breeders and other agricultural scientists: Indian pearl millet; Senegal pearl millet; USDA corn lines backcrossed to HtN by Dr. Gevers, South America; Philippines DMR 1, 2, 3, 4, 5, and 6; PRC lines obtained from mainland China by Dr. G. F. Sprague.

During 1975 a series of three plots were established for the chemical control of stripe rust at three locations in Northeast Oregon. One half of each plot was uniformly inoculated with uredospores of Puccinia striiformis Bubak. & Henn. in the fall and the other half in the spring. Two systemic fungicides (Plantvax EC and BAS 317-03 F) were applied. The plots were arranged so that each subplot received only one application. Treated (Maneb M-45) and untreated controls were included in each field. The systemic fungicides were applied with "Turbair" applicator at ULV dosage rates. Increased yields of at least 25% were obtained from each of the plots treated with the systemic fungicides.



Data from epidemiological studies on stripe rust of wheat in northeastern Oregon in 1968 and 1969 were reexamined and summarized to furnish information applicable to predictive model development. Five plots representing a range of rainfall amounts had been inoculated with uredospores of stripe rust in a 2.3 m<sup>2</sup> center. Physical environment was monitored and disease amounts were sampled at points along 8 equally spaced lines radiating from the focus. Rates of disease increase varied from 0.28 at Madras in 1968 to 0.04 at Rew in 1969. Upwind and downwind gradients; correlation of time and amount of rust with yield reduction yielded information for predictive model use.

Cooperatively with R. E. Ramig, ARS, observations were made on a 45-year continuous wheat experimental plot at Pendleton, Oregon indicating a direct relationship between sulfur bearing fertilizers and stripe rust of wheat. Incidence of stripe rust on Paha wheat was higher in those plots having a higher residual sulfur content of the soil than in those plots with lower residual sulfur. Tissue analysis of the flag leaf of the host indicated a greater sulfur content also.

St. Paul, MN (Bushnell, McVey, Roelfs, Rothman, Rowell): The potential for controlling stem rust by factors for low receptivity to infection, i.e. characters that result in reduced amounts of infection per unit of plant tissue for a given amount of virulent inoculum, was assessed. In isolated plots that reduced inoculum interference, rust developed about 14 days later and caused only 1/4 of the crop loss on cultivars with low receptivity associated with SrTt-1 than on those with high receptivity.

Evaluation of low receptivity in winter and spring wheats revealed difficulties in distinguishing between adult plant resistance (possibly due to Sr2) and characters for low receptivity to infection in cultivars with Hope in the pedigree. Among other hard red winter wheat cultivars, Apache and Blackhull had distinctively low receptivity to infection, but many of the remaining cultivars tested were found to have intermediate receptivity that resulted in about 1/2 the amount of infection that occurred on highly receptive cultivars. All spring wheat cultivars with the resistance gene SrTt-1 had very low receptivity to infection with the virulent race 15B-TLM. Among the remaining cultivars tested, many had moderately low to intermediate levels of receptivity, and Canthatch was distinctively low.

The evaluation of a group of oat cultivars for low receptivity to infection failed to detect any with the distinctively low levels detected in some wheat cultivars. The lowest ranking cultivars were two A. sterilis lines of known slow-rusting characteristics, Lodi, Jostrain, Joannette, Victoria, Stout, and Black Mesdag.

Comparative tests were made with mixed inocula of viable wheat and oat stem rust uredospores to detect differences in infectivity. In the field, wheat stem rust gave 2 to 4 times as much infection as oat stem rust on mature plants. Under artificial conditions, wheat stem rust gave slightly higher amounts of infection than oat stem rust on seedlings, but not on adult plants.

In the regional nurseries, those lines and cultivars having SrTt-1 had a lower severity reaction and percentage of infection to stem rust than entries without SrTt-1. Selections were made in the resistant materials from the breeding nurseries and advanced to the next generation for further testing.

Crosses were made and advanced to the F<sub>5</sub> by the method of single seed descent to transfer the leaf resistance of FR19 into lines of the Minnesota breeding program.

Four hundred entries in the newly acquired USDA Avena fatua collection were screened for new stem rust resistance genes. None were identified. Likewise, no resistant genes were found among the nine new plant introductions obtained by the USDA during the year 1974.

Several promising selections with high crown rust and stem rust resistance--and possibly combined crown and stem rust resistance--were identified among progenies in the interspecific oat crosses involving the diploid species Avena longiglumis and A. strigosa; and the two tetraploid species A. barbata and A. magna.

Lines were developed by combining the seedling resistance gene pg-12 with the adult plant gene pg-11 and also with the slow-rusting characteristic of Avena sterilis. Both lines are immune or highly resistant to all presently known races of stem rust in the seedling stage and as adults are more resistant than all other lines in the nursery.

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NRP Annual Report  
FY 1976

NRP 20280 Weed Control Technology for Protecting Crops, Grazing Lands,  
Aquatic Sites, and Noncropland

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I. Selected Examples of Significant Research Accomplishments

A. Mission: The mission of the Agricultural Research Service (ARS) is to provide the technology needed to assure an adequate supply of food, feed and fiber, and a quality environment. Weed control technology is essential to achieving this mission. ARS-NRP 20280, Weed Control Technology, is in direct support of the missions and goals of ARS and the Department. This NRP is organized into 71 projects at 31 locations. The program is conducted in cooperation with several Federal agencies, State agricultural experiment stations (SAES), private universities and research institutes, and industrial research organizations.

The research directly supports the provisions of the Federal Noxious Weed Act (FNWA) of 1974, which is administered by the Animal and Plant Health Inspection Service (APHIS), educational programs of the Extension Service (ES), operational programs of the Soil Conservation Service (SCS), and the Agricultural Stabilization and Commodity Service (ASCS), U.S. Department of Agriculture. It also aids in meeting the pesticide registration requirements of the Federal Insecticide, Fungicide, and Rodenticide Act, and other regulatory or operational programs of the United States. Environmental Protection Agency (EPA); Tennessee Valley Authority (TVA); Food and Drug Administration (FDA); Drug Enforcement Administration (DEA); Department of Defense (DOD); and the Bureau of Reclamation, Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service, and National Park Service, U.S. Department of the Interior; and other Federal agencies.

The major objectives of ARS-NRP 20280 are to develop: (a) fundamental knowledge of the biology, ecology, and biochemistry of weeds and weed populations, and principles and mechanisms for their control by biological, chemical, cultural, ecological, mechanical, physical, and integrated systems that are safe and will avoid or minimize hazards to the environment; (b) new and improved weed control technology that will increase efficiency in the production of food, feed, and fiber crops; and (c) methods that will reduce losses in yield and quality, and the cost of control and energy requirements in crops, grazing lands, ornamental plantings, aquatic sites, and noncropland.

The major purpose of this research is to develop principles of weed science and safe and efficient principles and practices of weed control that can be integrated with other production and protection technology to assure high-yielding food, feed, and fiber agroecosystems that maintain the Nation's food supply and improves the quality of the environment.



## B. Technological Objectives:

Technological Objective 1: New and improved fundamental knowledge of the biology of weeds for development of safe, new principles and mechanisms of their control by biological, chemical, cultural, ecological, physical, and integrated methods that will avoid or minimize hazards to nontarget organisms and to other components of the environment.

### Biology of Weeds

Stimulation of germination in dormant weed seeds by synthetic nitrogen-containing germination stimulants is affected by inhibition of an enzyme decomposing peroxide. This inhibition, coupled with the spared peroxide used for regeneration of critical reductants, allows the respiratory processes required for germination to proceed. Dormancies in weed seeds that may be overcome by light are also influenced by powerful hormonal substances of natural occurrence. The two stimulants combined act in an additive or synergistic manner, but the hormonal substance requires the presence of the stimulant induced by light exposure to act in certain species. The results of this research aid in identifying vulnerabilities in the germination, dormancy, and viability of weed seeds. This information can also be used to improve weed control practices. (R. B. Taylorson, Beltsville, MD)

A computerized list of the important weeds of the United States is being developed, including standardized common and scientific names with correlated ecological and biological data. This profile of the taxonomy, ecology, and related biological information will be used in a data bank on general biological and ecological data that contribute to the total technology needed to improve our understanding of weeds and to increase the efficiency of control methods. (R. A. Darrow, Frederick, MD)

The interacting effects of ultra-violet light, an adjuvant, and 2-4,D on the growth of crops and the selective control of weeds was determined. The adjuvant significantly increased the phytotoxicity of 2-4,D. A simple mathematical concept for comparing the effectiveness of herbicides by utilizing dose response curves was developed.  $GR_{50}$  values (the amount of candidate herbicides required to cause a 50 percent reduction in growth) were used to compute an efficiency ratio (ER) for each candidate herbicide. These and related techniques were implemented in a program to study the structure-activity relationships of herbicides and growth regulators on weed seed production, seed shedding, and subsequent germination. The evaluation data are being recorded so that computerized analyses can be rapidly completed. (W. Hurtt, Frederick, MD)

In research on seed germination, it was discovered that seeds of prickly sida, velvetleaf, and common purslane became dormant as they developed on the mother plants. Mother plant growth in low inorganic nutrient levels or under warm temperatures, resulted in increased dormancy of purslane seeds. In addition to the hard seed coat condition, inhibitor-promoter levels were important in the germination and dormancy of velvetleaf and prickly sida seeds. Inhibitors in the endosperm of velvetleaf prevented germination of both immature

and newly matured seeds. Ethylene, zeatin, and carbon dioxide promoted, and abscisic acid prevented germination of embryos from dormant velvetleaf seeds. Aging reduced velvetleaf and prickly sida dormancy. In prickly sida seeds, an increase in growth promoters correlated with early stages of germination. Polysome (protein synthesizing substances) levels increased in light-sensitive purslane seeds just prior to germination. Also, physiological evidence was developed which identified the causes of changes in photosensitivity of dormant seeds. Impermeability of seed coats to water was a major factor enhancing weed seed longevity in soil. Over 50 percent of velvetleaf, johnsongrass, purple moonflower, and spurred anoda seeds were viable after 2-1/2 years in a 50-year seed burial study. The results of this basic research are proving useful in developing a better understanding of the reproduction of weeds, in identifying periods of vulnerability, and the development of principles of weed control. (G. H. Egley, Stoneville, MS)

The reproductive biology of plants was shown to be altered by several factors, one of which is competition. Interspecific competition in johnsongrass delayed the formation of rhizomes and panicles and reduced the final dry weight of reproductive parts. Intraspecific competition of purple nutsedge stimulated tuber formation, shifting dry weight from floral structures to tubers. The determination of mechanisms by which such shifts in reproduction occur provides insight as to the reason for yield reductions caused by competition and provides new approaches to developing improved methods of weed control. (R. D. Williams, Stoneville, MS)

#### Behavior, Fate, and Effects of Herbicides in Plants and Soils

Fifteen new candidate herbicides were compared with the best standard herbicides currently available as preplanting soil-incorporated, preemergence and postemergence treatments for the control of a broad spectrum of broad-leaved weeds and grasses in 15 field and horticultural crops at Beltsville, MD. The results of these studies showed that excellent progress is being made in developing new, improved herbicides that are highly specific and selective for the control of a diverse spectrum of weeds in field and horticultural crops. Corn, cotton, soybeans, peanuts, sugarbeets, flax, and safflower were highly tolerant to several of the new candidate herbicides that gave excellent weed control without crop injury. Evidence of greater specificity and wider margins of selectivity with optimum residual weed control effectiveness were characteristics of several of the new candidate herbicides. The results of these investigations show that several of these candidate herbicides warrant secondary and advanced field evaluation studies to confirm these preliminary results and to determine their usefulness for weed control nationwide. (W. A. Gentner, Beltsville, MD)

A new, biodegradable, starch-encapsulated, controlled-release formulation has demonstrated that the residual weed control effectiveness, safety to crops, and overall performance of several herbicides can be significantly improved. Cooperative research between chemists at Peoria, IL, and weed research scientists at Lafayette, IN, showed that a new controlled-release formulation of EPTC gave approximately 100 days of weed control as compared to approximately 30 days for the conventional emulsifiable concentrate. The results of these investigations indicate that further improvements can be made in the



efficacy and safety of herbicides through development of controlled-release formulations. (M. M. Schreiber, Lafayette, IN, and W. M. Doane, Peoria, IL)

A new agroecosystem chamber was developed to determine the fate of herbicides in the environment. The new chamber can be used to monitor the fate of herbicides in soil, water, plants, and air simultaneously under simulated field conditions. The advantages of the chamber are that experiments can be conducted at lower cost, on a year-round basis under reproducible conditions, on more than one herbicide at a time, in a nonhazardous and nonpolluting manner, and with results related to known environmental conditions. These new agroecosystem approaches to evaluating herbicides should provide better efficacy and safety data which can be used to support the registration of herbicides or to identify undesirable environmental effects. Evaluation techniques such as the agroecosystem chamber, which can be used rapidly and effectively, will also be helpful in supporting the pesticide assessment program in ARS. (R. G. Nash, Beltsville, MD)

An enzyme, arylacylamidase, that degrades the herbicide propanil has been isolated from several plants, partially purified, and characterized. Its properties from several different plants were found to be similar. Some weeds that have high amounts of the enzyme are resistant to the herbicide propanil, while those that do not have the enzyme or only low levels of it are highly susceptible and are effectively controlled. These results are important in understanding the selectivity and metabolism of herbicides in plants and provide new and important approaches to the discovery, synthesis, and development of new and improved herbicides. Since these herbicides are so specific in their action, they are usually low in mammalian toxicity and therefore more efficient and safer to use for selective weed control. (R. G. Hoagland, Stoneville, MS)

Nitralin and trifluralin, two widely used herbicides, when applied to field soils dissipated to a low level within about 3 months even with repeated applications at high dosage rates. These results show that normal rates of nitralin and trifluralin may be applied annually without significant residual phytotoxicity on succeeding crops in the rotation. Sorption equilibria research with several herbicides are providing data that will be useful as a basis for developing a predictive capability related directly to herbicide availability in various soils. Metribuzin has been evaluated for its adsorption equilibria, mobility, and residual activity in soils. These results show that the herbicide is easily desorbed, is quite mobile in soil, and degrades rapidly with a half-life of about 30-40 days. Research of this type, on performance efficiency and crop safety, is essential prior to wide-spread use of selective herbicides as soil applied treatments for weed control. (K. E. Savage, Stoneville, MS)

Several herbicides have been studied to determine their runoff potential following soil applications or applications to growing crops on watersheds. The results show that herbicide runoff is 1 percent or less of the amount applied for all herbicides investigated thus far, including water soluble and insoluble chemicals. The runoff losses of naturally present arsenic in soils has been compared to the runoff of arsenic resulting from the application of



arsenical herbicides. The runoff from plots treated with organic arsenical herbicides has been small to nonexistent. The arsenic content of soybeans grown in fields adjacent to cotton fields treated with arsenical herbicides was negligible if the arsenical herbicides were applied for weed control in cotton in accordance with label instructions. Arsenic behavior in soils has been shown to be similar to phosphate and that movement with water through clay soils is very slow. The results of this research and previous extensive studies indicate there is little risk of contaminating crops grown in rotation with cotton treated with arsenical herbicides for weed control. (R. D. Wauchope, Stoneville, MS)

Technological Objective 2: New and improved weed control technology for use in field crops that will increase efficiency in food, feed, and fiber production, reduce losses in yield and quality, and reduce the cost of control.

### Small Grains

Wild oat reduces annual wheat yields, causing losses--not including costs of control--of more than \$0.5 billion each year. Current wild oat and other weed control practices in grain crops are not as satisfactory as desired. New cultural and chemical methods of controlling wild oat and other weeds in wheat and other crops are being developed through research on a new herbicide, diclofop, which is effective and provides reliable control under a wider range of environmental conditions. Diclofop will supplement currently available herbicides and give control of wild oat and other weeds, especially under conditions in which some of the current herbicides have not been as effective as desired. It kills wild oat by inhibiting a natural plant hormone. It does not damage wheat because the herbicide does not inhibit hormone action in wheat. Also, wild oat converts diclofop to a different chemical which kills the wild oat; but wheat converts the herbicide to harmless products and is not damaged. This example illustrates the value of basic research in determining the mechanisms and sites of action and metabolism of herbicides in plants and how such basic information can be used by industrial organizations to speed up the development of highly selective and safe herbicides with little or no risk to crops or to the environment. (R. H. Shimabukuro, Fargo, ND)

### Rice

Crop and herbicide rotations in agroecosystem approaches have proven effective for the control of red rice and other hard-to-kill weeds in rice. An effective agroecosystem involves the use of rice and an alternate upland crop treated with herbicides specific for red rice. Two years of the alternate system made it possible to grow high yields of rice after 3 years of the rotation. New herbicides, including benthocarb, bifenox, bentazon, butachlor, oxadiazon,  $\text{KN}_3$ , and  $\text{NaN}_3$  integrated into a weed management system which included standard herbicides such as propanil, molinate, or phenoxy herbicides controlled weeds better than the standards alone or combined. A fungus disease has been developed for the first time which is being used commercially to control northern jointvetch in rice. Aerial applications of spores of the pathogen controlled 98 percent of northern jointvetch in 43 commercial rice fields on more than 1,400 acres during the past 3 years. (R. J. Smith, Stuttgart, AR)

### Soybeans

New application techniques improved the efficiency of herbicides, reduced the amount used, and lowered the cost of johnsongrass control in soybeans. A new circulating sprayer permitted the use of herbicides for the control of johnsongrass and other difficult to control weeds that could not be controlled by conventional equipment. It applied herbicides such as glyphosate across the rows of soybeans in contact with weeds such as johnsongrass, killing the

weed without damaging the crop. In addition, 60 to 90 percent of the total herbicide sprayed is recollected by the sprayer and reused. This avoids the excessive use of herbicides, reduces the cost of control, decreases the toxicity of herbicide to soybeans and adjacent crops, increases its effectiveness on the weed, and reduces the risk of environmental effects. The new circulating sprayer is being rapidly developed and sold widely in the United States and abroad by several industrial organizations. (C. G. McWhorter, Stoneville, MS)

Significant differences were found in the tolerance or susceptibility of soybean cultivars and breeding lines to several herbicides. Studies on the inheritance of bentazon sensitivity in soybeans demonstrated one of the few examples of simply inherited sensitivity of cultivars to a herbicide. These data provided scientists with an experimental approach to use in studying the basis of selectivity of bentazon. The basis of selectivity on susceptible and tolerant species was found to be due to a combination of differential metabolism and translocation of bentazon within plants. Studies on the growth habits, morphology, and life cycle of nutsedge, and the use of the most effective herbicides for nutsedge control, provided the basis for development of a selective system for the control of this weed. The system that gave the most effective control involved preplanting tillage, the use of herbicides and mixtures of herbicides, high soybean populations per acre, and cultivation. (L. M. Wax and E. W. Stoller, Urbana, IL)

#### Peanuts

Basic field research has clarified the competitive interrelationships between peanuts and several of the most difficult-to-control and troublesome broad-leaved weeds. This information enhances the use of cultural practices and the application of herbicides for maximum weed control effectiveness, with minimum to nonexistent effects on the crops and environment. These studies also resulted in the discovery of a new method of controlling weeds in peanuts with dinoseb. Investigations on pesticide interactions in peanut production have established those that increase the yields and improve the quality of peanuts and also those interactions that tend to reduce the yield and quality of peanuts. These new and improved principles and practices of weed control are now being used on more than 95 percent of the peanuts grown in the United States and on an increasing percentage of the peanuts grown in foreign countries. The annual value of this technology to United States peanut producers is about \$10 million in increased yields alone. In addition, market quality research, organoleptic studies, and chemical analyses have been conducted on the effects of all chemical practices, and the results of this research indicate that no harmful effects result to peanuts or peanut products from the practices used to control weeds. (E. W. Hauser, Tifton, GA)

#### Sugarcane

In a 3-year crop cycle experiment at Houma, LA, sugarcane yields were about average without cultivation when the weeds were controlled with herbicides. Annual weeds were effectively controlled by herbicides without cultivation, but some cultivation was needed to control purple nutsedge. In cooperative research it was determined that itchgrass, a new weed causing serious damage in sugarcane in the United States, can produce mature seed as far north as



St. Paul, MN, and has the potential to infest many crops throughout the South and Midwest. Under field conditions, itchgrass primarily germinates from the top 4 inches of soil and the first internode of deep germinating seedlings ceases to elongate and is killed after entering a layer of soil treated with the herbicide trifluralin. Asulam was more effective in controlling johnsongrass in sugarcane than dalapon, the standard herbicide used for this purpose. The results of this research were used to obtain a registration of asulam by EPA for weed control in sugarcane. The results of basic field research showed that the herbicides, fenac and terbacil, that are widely used to control weeds in sugarcane, do not contribute to the low yields that have been experienced by the sugarcane industry. (R. W. Millhollon, Houma, LA)

### Sugarbeets

Twelve new experimental herbicides for weed control in sugarbeets were evaluated during the past 3 years. Of these 12, ARS research at Ft. Collins, CO, contributed to the registration of desmedipham and ethofumesate. Both of these herbicides will supplement existing chemical and cultural methods of control and provide farmers with better alternate choices for the control of broadleaved annual weeds and grasses. Ethofumesate also provides greater residual effectiveness for control of annual weeds, thus reducing the chances of late-season competition. (E. E. Schweizer, Ft. Collins, CO)

Weed control methods previously developed for each of three distinct periods of the sugarbeet growing season have been integrated into a system of full season weed control which brings the crop to harvest, free of weeds, with a 90 percent reduction in hand labor requirements, and for a cost of \$50 per acre, compared with \$110 per acre when traditional methods were used. In cooperative research with two industrial organizations, several special controlled-release formulations of chloropropham were developed. One formulation controlled dodder for periods four times as long as the standard commercial emulsifiable concentrate formulation of the same chemical applied at the same rate. This was some of the earliest research to demonstrate a significant advantage for the development of controlled-release technology for herbicides. (J. H. Dawson, Prosser, WA)

### Cotton

Twenty-one insect species were evaluated for purple nutsedge control and two showed outstanding promise as potential biocontrol agents. One of the insects is a moth that is host-plant specific. It has been studied in detail and a diet and cultural method have been developed to provide a continuous supply of insects for purple nutsedge control. The effectiveness of this insect for nutsedge control has ranged from 55 percent reduction in the weight of shoots under greenhouse conditions to 33 percent for a single application under field conditions. The successful development of this insect for purple nutsedge control would make it feasible to use the insect on approximately 3 million acres of cotton to reduce the losses currently caused by purple nutsedge. (K. E. Frick, Stoneville, MS)

A six-year basic field study designed to evaluate the effects of repeated applications of herbicides on cotton and their behavior and fate in western irrigated soils has been completed. The results showed that no significant accumulation of herbicides occurred in soils or plants and that most of the herbicides were confined to the tilled zone of soil. This research demonstrates that, with proper use, the herbicides are not likely to cause undesirable impacts on the soil or other components of the environment. Evaluation research on seven new dinitrobenzamine herbicides demonstrated that they varied in plant and soil persistence and were not equally effective for weed control in cotton. Profluralin and trifluralin provided the combination of best weed control, least cotton injury, and least residual residues in the soil. Field studies revealed that yellow nutsedge, when permitted to compete with cotton for greater than four weeks, delayed maturity and reduced the yields of seed cotton. Compared to weed-free cotton, 6, 8, and 25 weeks of nutsedge competition reduced yields 20, 20, and 34 percent, respectively. (J. H. Miller and P. E. Keeley, Shafter, CA)

#### Forage Seed Production

In research at Corvallis, OR, ethofumesate selectively controlled winter annual weed grasses in Italian ryegrass seed fields without adversely affecting Italian ryegrass seed production. Techniques were developed to use winter cover crops and glyphosate to enhance the use of chemical fallow to control weeds during the establishment of grasses for seed production on sloping fields where water erosion previously prevented the use of this practice. The combination of carbon banding followed by applications of diuron and ethofumesate controlled all weeds in fall-planted turf type perennial rye grass, making it possible to produce high-quality turf grass seed the first summer after a fall-planting. Ethofumesate was also found to be more effective than other herbicides in controlling annual bluegrass (a weed grass) in established turf grasses such as Kentucky bluegrass, bentgrass, and perennial rye grass seed fields. This research led to the registration, by EPA, of these practices which can now be used by farmers. (W. O. Lee, Corvallis, OR)

#### Crop-Herbicide Rotations

Basic field research has demonstrated the value of rotating crops, rotating herbicides, and rotating mixtures of herbicides for controlling weeds. Research to investigate intensive cropping systems has also demonstrated the value of integrated technologies for multiple pest management. A broad spectrum of annual weeds can be controlled in corn, cotton, and soybeans, using weed control systems based on cultural and chemical practices. In selected rotations, crop production exceeded average grower production by two or more times per unit land area. Weeds were effectively controlled in cropping sequences of agronomic and horticultural crops. Three or more crops can be harvested on the same land unit each crop year without an accumulation of herbicide residues in soils or crops. Net annual returns per acre exceeded \$1,000 per acre under intensive cropping sequences to control weeds, as compared to about \$500 per acre using conventional cropping systems. (C. C. Dowler, Tifton, GA)



Technological Objective 3: New and improved weed control technology for use in horticultural crops that will increase production efficiency, reduce losses in yield and quality, and reduce the cost of control.

In a 7-year study to determine the effects of repeated annual applications of selected herbicide treatments on plant vigor, yield, and weed control in highbush blueberries, results showed that terbacil and diuron at normal use rates could be applied annually to control weeds and improve crop quality and yields. Fluometuron caused no reduction in the yield of blueberries during the first 3 years. However, yields were seriously reduced from the fourth year on and demonstrated that this chemical could not be used for repeated annual applications in this crop. Apple varieties varied significantly in their tolerance or susceptibility to the herbicide terbacil, used to control weeds in a long-term study. Several varieties were highly tolerant and the herbicide did not cause reductions in yield. However, several varieties exhibited severe foliar symptoms, and the herbicide caused reductions in the rate of growth and severe reductions in yield. Weed competition from a narrow 12-inch strip of weeds in the tree row resulted in marked reductions in the yield of peaches. The results of this study showed clearly the importance of complete weed control in the tree row. (W. V. Welker, New Brunswick, NJ)

New and improved application techniques for two highly selective herbicides for several vegetable crops were developed. Mechanical devices that incorporated the herbicides into the soil at various depths improved the weed control performance efficiency and safety of the herbicides to the crops. Movement and persistence patterns for several major herbicides in furrow irrigated soils showed that soil applied bensulide, DCPA, and trifluralin were not moved appreciably downward in soil after rainfall, once the applications were stabilized with mechanical devices that incorporated them at various depths. Herbicides did not accumulate after 3 annual applications, but higher rates of application, deeper soil incorporation, and reduced tillage extended the residual activity of the herbicides in the soils for up to 13 months. UHF electromagnetic energy controlled several herbicide resistant weed species without injury to field grown canteloupes and onions. Soil temperatures were increased by UHF and weed seed germination was inhibited for 7 months, indicating toxicity in dormant seeds. The research established the technical feasibility of UHF electromagnetic energy as a weed, disease, and nematode control technique without leaving chemical residues in crop production soils. (R. L. Menges, Weslaco, TX)

Perennial weeds such as Canada thistle were controlled by soil fumigation without using gas proof covers. Activated carbon, banded over the seeded row, protected direct-seeded asparagus from herbicide injury without impairing weed control. The use of herbicide combinations for weed control in potatoes broadened the spectrum of weed control and resulted in higher potato yields, greater crop safety, and reduced production costs. A program for the control of weeds in hops was developed using properly timed and repeated applications of a mixture of two herbicides. The selection of a herbicide for weed control in fruit tree nurseries depended on the weeds to be controlled and the fruit tree root stock to be grown. (A. G. Ogg, Jr., Prosser, WA)



Technological Objective 4: New and improved weed control technology for use in forage crops, pastures, rangelands, and turf that will increase efficiency of food and feed production, improve aesthetic values, reduce losses in yield and quality, and reduce the cost of control.

Eight herbicidal treatments applied to a turf mixture of red fescue and Kentucky bluegrass in each of 3 years of an experiment controlled crabgrass adequately. At the end of the third year, Kentucky bluegrass had increased in its proportion of the turfgrass species from 3 to about 40 percent in plots treated with benefin, butralin, DCPA, and profluralin. In experiments where herbicides were used to renovate turf areas, glyphosate showed particular promise for nonselective control of such hard-to-kill species as Bermudagrass, zoysia, and bentgrasses. For complete control of these species, two or more repeated treatments about 5 to 6 weeks apart within a growing season were required. (D. L. Klingman, Beltsville, MD)

In cooperative research, a strain of birdsfoot trefoil resistant to 2,4-D was developed. Weed control and minimum tillage technologies for establishing forages on hill and pasture lands, as well as high producing agricultural lands, were developed. New methods for the control of yellow nutsedge and other perennial weeds were also developed as aids in the establishment of forages. (D. L. Linscott, Ithaca, NY)

Chemical treatments involving the use of tebuthiuron were developed for control of yaupon post oak, blackjack oak, live oak, winged elm, hickory whitebrush, and huisache, which are damaging brush species on millions of acres of rangelands of the Southwestern United States. New methods of herbicide application were developed that reduced herbicide drift and forage injury and maintained or increased brush control effectiveness. Tebuthiuron residues were monitored in surface runoff water, soil, and native grasses. Residues of tebuthiuron disappeared relatively rapidly from the environment under central Texas conditions and did not contaminate or pollute soil, water, and other components of the environment. (R. W. Bovey, J. R. Baur, and R. E. Meyer, College Station, TX)

Aerial chemical application technologies for economical control of shinnery oak and sagebrush were developed. Forage production increases have ranged from 30 to more than 60 percent. (E. H. McIlvain, Woodward, OK)

Long-term studies of weed grass-crop competitive associations indicate that giant foxtail's domination is due to more than its ability to compete for water and nutrients. Research on allelopathic effects are being continued to determine the role of secondary chemicals in weed-crop competition. (M. M. Schreiber, Lafayette, IN)

Earlier research on the penetration of chemicals into leaves has shown that foliar-applied chemicals enter leaf tissue either directly through the cuticle or stomates. However, recent research on velvet mesquite leaflets utilizing fluorescence microscopy demonstrated that the leaf hairs can also be major portals of entry. Penetration through the leaf hairs, in comparison with the usual mode of entry, was found to be a function of species and leaf maturity. Also the optimum formulation of the chemical spray solution and of the surface active agent included with it was found to be different for the different

routes of entry. This basic research indicates that it is essential to tailor the surfactant for herbicidal formulations for maximum penetration, adsorption, and translocation, depending on species, the degree of foliar development, and on growing conditions at the time of treatment. (H. M. Hull, Tucson, AZ)

Tebuthiuron provided excellent control of creosotebush, wait-a-minute bush, catclaw acacia, and velvet mesquite at rates of 0.5 to 1.0 lb per acre. Prickly pear and cholla cacti were controlled with 1 lb per acre rates of granular picloram. Treatment of velvet mesquite once with a mixture of picloram and 2,4,5-T gave the same degree of control as two treatments with 2,4,5-T. Preliminary data indicate that when the volume of water from a treated watershed increases, the concentration of herbicide in the water also increases. When used according to directions on the label, most herbicides do not adversely affect honey bees directly but do eliminate critical forage plants in many situations. (H. L. Morton, Tucson, AZ)

Improved control technologies have been developed for medusa head, scotch thistle, downy broom, and associated weeds on rangelands. These technologies include the use of atrazine-fallow and paraquat-direct seeding methods. A basic understanding of the ecology and biology of rangelands species, communities, and ecosystems has been furthered by research on microenvironmental monitoring, seed germination, phenology of individual species, competition, and on other facets of weed-crop ecology. Basic research of this type provides a basis for improving weed control technology without causing undesirable environmental impacts on rangelands. (R. E. Evans, R. E. Eckert, J. A. Young, Reno, NV)

Saponins were isolated and identified as the principal toxic compounds in alfombrilla and drymary. Nitro compounds were isolated and identified as the toxic agent in 263 species and varieties of North American (Astragalus and 33 species of Old World and South American Astragalus. A. falcatus, an introduced species, was found to be highly poisonous. Poisonous compounds were also characterized in several other introduced species that kill significant numbers of livestock on western rangelands. This basic research provides the knowledge needed to restrict the entry of alien weeds and to develop weed control and grazing management systems that will prevent or reduce livestock losses from poisonous weeds. (M. C. Williams, Logan, UT)

Control technology for tall larkspur was developed which prevented cattle losses from poisoning, improved grass production, and permitted grazing management practices to further improve forage production. These technologies were developed and implemented without endangering the watershed or wildlife habitat. A savings of \$13,500 by preventing cattle losses was realized from using these technologies on a 2,000 acre pasture in a 5-year period with an expenditure of \$2,000 for larkspur control. The development and implementation of these technologies illustrate the cost effectiveness of this research when it is known that similar savings could be realized on many thousands of rangeland acres infested with larkspur and other poisonous weeds. (E. H. Cronin, Logan, UT)

During the past 3 years a practical modified rangeland drill was developed for seeding in stoney soils and rough terrain. Reliable chemical methods were developed for controlling competitively and mechanically injurious winter annual grasses such as downybrome and medusahead. The causes of seedling failure of planted species after weed control were determined to be primarily microbiological problems. Suitable chemical treatments were developed for control of the rapidly spreading, difuse knapweed, spotted knapweed, and yellow starthistle. Research was completed on the life history, ecology, and control of dalmation toadflax. We also developed a basic physiological understanding of translocation of herbicides in western bracken, a poisonous fern of worldwide distribution that damages livestock. (W. C. Robocker and R. D. Schirman, Pullman, WA)



Technological Objective 5: New and improved weed control technology for controlling, managing, or using weed populations to improve water quality, fish and wildlife habitats, and recreational areas in aquatic and noncropland sites.

Developed a technique for controlling certain submersed aquatic weed growth in areas of limited water exchange through controlling regrowth with chemical retardants. Cooperated in the development of efficacy and residue data to support registration of glyphosate for control of weeds on ditchbanks. Established the relationships between eutrophication and aquatic weed infestations and determined that it was not feasible to improve water quality in South-Florida canals by renovating waste water in the everglades marshes. (K. K. Steward, Fort Lauderdale, FL)

The growth of alligatorweed, waterprimrose, and smartweed was inhibited by low oxygen or submergence in the dark, and is promoted by red light, hydrogen peroxide, or exposure to air. Photosynthesis-inhibiting-herbicides were more effective against submerged than partially submerged aquatic weeds. The alligatorweed stem borer moth was developed for the control of alligatorweed. It migrated from Florida, through Mississippi, to Arkansas, Louisiana, and Texas in 1974 and 1975 and has produced 50 to 90 percent biocontrol of stable, floating mats in the northern reaches of the alligatorweed's range in the Mississippi Valley. This insect and the alligatorweed flea beetle have produced 90 to 95 percent biocontrol of alligatorweed in the more southern reaches of the alligatorweed's range of adaptation. (P. C. Quimby, Jr., Stoneville, MS)

Techniques were developed for the successful use of cocoamine derivatives of endothall for the control of submersed aquatic weeds in large bodies of water in California. Allelopathic relationships between spikerush and pondweeds were demonstrated and the mechanisms of competition that exist among these plants in nature is being determined. Spikerush offers a new potential method of biocontrol for pondweeds and other weeds in irrigation channels. (P. A. Frank, Davis, CA)

A treatment using a combination of diquat plus copper sulfate pentahydrate was developed which controlled dense infestations of filamentous algae in salmon-spawning channels and aquatic weeds in farm ponds and did not damage fish production. A seed nursery for the aquatic weed competitor, dwarf spikerush, was established and techniques for harvesting cleaning, storing, and germinating the seed of this species were developed. This basic research will provide the technology needed to produce new seed sources for a large-scale pilot aquatic weed control management system for irrigation water conveyance systems. (R. Yeo, Davis, CA)

The dissipation rate of the herbicide dalapon in moving water was determined and residues of dalapon in crops irrigated with herbicide treated water were also established. Data on the efficacy and dalapon residues were submitted in a petition to EPA to support registration of this herbicide for use in irrigation systems. The dissipation and fate of the herbicide glyphosate in a slow-moving earthen canal and a fast-moving cement-lined canal were

established. These data are also being submitted to EPA to support a petition for an experimental use permit for glyphosate for control of weeds on irrigation systems. (L. W. J. Anderson, Denver, CO)

Eighteen selections of reed canarygrass collected from a wide geographical area varied widely in their growth habits, reproductive capacities, and in response to selective weed control by chemicals at a common site. Redtop and creeping red fescue grasses were more satisfactory as replacements for weeds, controlled by herbicides on ditchbanks, and both species were found to be more tolerant to herbicides than reed canarygrass. Glyphosate was effectively used to control other weeds in stands of creeping red fescue, but reed canarygrass seedlings were very susceptible to rates of this herbicide that killed other types of weeds. Glyphosate applied for the control of undesirable vegetation on dry irrigation canal banks did not produce a residue in the water when the canals were filled. When glyphosate was injected directly into flowing water, 30 percent of the herbicide was lost in the first mile, but only about 12 percent was lost in the next 4 to 8 miles. Six crop plants, furrow- or sprinkler-irrigated with water containing glyphosate at concentrations up to 2.2 ppmw for 8 hours (1.0 lb/acre) were not injured or did not contain herbicide residues at harvest time. The results of this research show that the performance efficiency of glyphosate and the residues associated with its use would not impair the quality of the water for crop irrigation. These data should eventually lead to the registration of glyphosate for controlling weeds along ditchbanks. (R. D. Comes, Prosser, WA)

## II Other Significant Accomplishments

### 1. 1976 Program Review and Report for NRP 20280

Nineteen criteria were used to analyze and evaluate the research programs of all ARS scientists who contribute to NRP 20280. This report, entitled "ARS-National Research Program 20280, Weed Control Technology for Protecting Crops, Grazing Lands, Aquatic Sites, and Noncropland," March 22, 1977, 320 pages, was distributed to all scientists, technical advisors, line managers, and administrators responsible for this research program. It contains a thorough spectrum of information that may be used to judge the productivity, needs, and benefits of this program.

### 2. Publications.

A complete list of publications is contained in the Program Review and Report for NRP 20280 cited in 1. above. The 63 scientists who contribute directly to NRP 20280 published 264 scientific papers and 137 abstracts in more than 20 scientific periodicals during the past year. Thus, the average was 4.2 scientific papers and 2.2 abstracts per scientist—excellent evidence of productivity.

Thirty-six of the 128 papers published in 1976 in Weed Science, Journal of Weed Science Society of America (WSSA), were authored by ARS weed scientists. This was 28 percent of the total which is far greater than the percentage of ARS weed scientists in the total WSSA research scientist membership.

### 3. Research Planning Conferences and Workshops.

ARS weed scientists organized and participated in several research planning conferences, workshops, and program reviews during the past year. These included:

a. Weed research planning conference in soybeans, Tifton, GA, September 20-21, 1976.

b. Weed research planning conference in cotton, Atlanta, GA, January 10-12, 1977.

c. Research planning conference on development of Colletotrichum gloeosporioides for control of northern jointvetch in rice. ARS-SAES-The Upjohn Chemical Company, Beltsville, MD, April 1, 1976.

d. First weed science research conference with cotton production-mechanization conference, Atlanta, GA, January 12-13, 1977.

e. Alleopathy research planning conference, State College, MS, March 15-16, 1977.

f. Research planning conference on controlled release technology for pesticides, Urbana, IL, November 17, 1976.



g. Research planning conference on arid and semiarid rangeland ecosystems, Temple, TX, April 5-8, 1977.

h. Weed scientists have participated in a variety of other workshops on crop production efficiency research.

4. Preparation of National Research Program 20280.

More than 112 ARS scientists contributed to the writing of NRP 20280 in 1975 and 1976. This provided an opportunity for all ARS weed scientists who conduct research in this field to contribute to the organization and composition of this national research program.

5. Professional Status of ARS Weed Scientists.

a. Since 1954, when the Weed Science Society of America (WSSA) was organized, eight of the sixteen presidents elected were ARS weed scientists.

b. Eight out of 31 WSSA Fellows that have been elected were ARS weed scientists.

c. Three out of four Outstanding Research Scientists Awards have been ARS weed scientists.

d. At the 1976 WSSA meeting, ARS weed scientists won the Most Outstanding Paper Award and the Most Outstanding Research Scientist Award. Also an ARS scientist was one of the three WSSA Fellows elected. In 1977, an ARS scientist won all three of these awards--an unprecedented achievement.

e. In addition to the participation of ARS weed scientists in a broad spectrum of WSSA, regional weed societies, and conference activities, they are also members and contribute papers to journals of the American Society of Agronomy, American Society of Plant Physiologists, American Association for the Advancement of Science, American Chemical Society, Society for Range Management, and more than 20 additional scientific organizations.

NRP Annual Report  
FY 1976

NRP 20290 Agricultural Chemicals Technology for Crops Protection and  
Modification

NPS Contact: W. C. Shaw

PACS Contact: L. L. Jansen

Selected Examples of Significant Research Accomplishments

I MISSION

Important missions of the Agricultural Research Service (ARS) are to: (1) develop the technology needed to assure and protect an adequate supply of high-quality food, feed, and fiber, and (2) improve the quality of the environment for man and animals. Technology for control of pests and plant growth modification is essential to achieving this mission. ARS-NRP 20290 is in direct support of the missions and goals of ARS and the Department.

This research is organized in 15 projects at 11 locations and is conducted in cooperation with several Federal agencies, the State agricultural experiment stations (SAES), private universities and research institutes, and industrial organizations. The research also supports the provisions of the Federal Noxious Weed Act of 1974 (FNWA) and aids in meeting the pesticide registration requirements of the Federal Insecticide, Fungicide and Rodenticide Act, and other regulatory programs of EPA and other Federal agencies.

This national program includes research to develop principles of efficient and effective pest control and plant growth modification that can be integrated with other production technology. This program is essential to obtaining high crop yields, reducing the cost of pest control, maintaining food quality, increasing efficiency of production, providing data for environmental impact statements, and developing technology to assure a quality environment.

The research will provide fundamental technology essential to the safe and efficient performance of chemicals for crops protection and modification of plant growth. It also provides fundamental data that are essential to the development of pollution prevention technology and to assure safety of food, feed, and humans.

## II TECHNOLOGICAL OBJECTIVES

Technological Objective 1: New concepts and knowledge for improving the primary evaluation and structure-activity assessments for enhanced development of improved herbicides, fungicides, nematocides, insecticides, and growth regulators that are compatible with a quality environment.

Camptothecin has been isolated and identified. This compound has been demonstrated to be a very effective plant growth inhibitor of several mono- and dicots, especially tall fescue and tobacco. It appears to function at a very early stage of cell division and is effective at concentrations as low as  $10^{-6}$  M. A complex tropone-lactone has been isolated from Cephalotaxus and appears to be an effective phytotoxicant. This compound is one of the most structurally complex terpenoids thus far identified and one of the few possessing significant biological activity. (J.G. Buta, Beltsville, MD)

Ether extract of about 400 plant species and plant parts supplied by the Biological Active Natural Products Laboratory were evaluated for their effect on germination of oat, bean, corn, lettuce, rape, tomato, and cabbage seed. Extracts were also applied as a spray to beans, corn, and tobacco to study their effect on growth and flowering. Several extracts were evaluated for auxin-type activity. In total, we found that 97 extracts representing 79 species and 36 plant families were active. The most active plant extracts came from Euonymus and Maytenus species of the staff-tree family (Celastraceae), two lichen sps., and from Caylusea of the Mignonette family (Resedaceae). Extracts from Cephalotaxus (plum yew) and from extracts of pine sps. inhibited apical growth. Buffaloberry extracts (Shepherdia) inhibited axillary growth of Xanthi tobacco when applied at high concentrations and stimulated growth at low concentrations. Several extracts inhibited or stimulated flowering of corn and beans. This study is still in progress. (W. J. Meudt, Beltsville, MD)

Discovered, with cooperators, nematocidal activity in several amides and amines, protein fractions similar in structure to insect juvenile hormones. They are so safe to vertebrates that several provide the "protein" parts of shampoos. Current objective is to learn how to make them practical for grower use. Cooperated in developing and evaluating controlled release versions of commercial nematocides with potential for greater efficacy and safety. Two of these, DMCP and diazinon formulations, retain nematocide when dry and release when wet, thus extending efficacy of lower total dosages. We have shown that one annual ethoprop treatment sharply improves growth, quality, and aesthetic appearance of bluegrass (parade ground, U.S. Military Academy). We have also shown that the treatment pays for itself by eliminating resodding and reducing yearly fertilizer applications on the parade ground by 25 percent, resulting in energy savings as well. (J. Feldmesser, Beltsville, MD)

Fifty new chemicals were evaluated in the field and 80 were evaluated in the greenhouse for herbicidal properties. Discovered 20 chemicals more effective for the control of yellow nutsedge than perfluidone. Twenty-five of 60 compounds evaluated for postemergence control of opium poppy and 15 of 45 compounds evaluated for postemergence control of marihuana were effective. The active



ingredients, concentrations greater than 8000 ppm in marihuana, were associated with soils containing more than 100 ppm extractable  $P_{2O_5}$ . Increases in the concentrations of morphine in P. somniferum and thebaine in P. bracteatum were related to increased levels of soil phosphorus. Spring fertilization with nitrogen resulted in higher thebaine yields from P. bracteatum than fall nitrogen fertilization. Twenty-four selected herbicides were studied for weed control in P. bracteatum. Herbicides may decrease alkaloids. Nine fungicides were applied as foliar treatments and 13 were applied as seed protectants to P. bracteatum. None of these caused significant injury. (W. A. Gentner, C. B. Coffman, and P. G. Vincent, Beltsville, MD)

Developed spray equipment for application of very low volumes, less than 2 gallons per acre, of pesticides; fungicide-bactericide formulations which can be used in ultra-low volume spray equipment; systems of protecting plants other than pesticide sprays; methods for rapid evaluation of disease resistance in stone fruit progeny originating from the breeding program; and determined the role of residue bacteria in the epidemiology of the fire blight disease. (H. L. Keil, Beltsville, MD)

A new technique for the injection of plant growth-regulating chemicals into woody plants has been developed as a research tool for the evaluation of these chemicals in plant growth modification. A miniature injection device allows direct, rapid application of any desired growth regulator into seedling stems or branches of woody plants with no hazard of release on adjoining or nontarget plants or into the environment. A rapid method for the detection of chemical defoliants of herbaceous and woody plants was developed using young cotton plants grown in a controlled environment after foliar treatment with several known defoliants. Cotyledonary leaf drop will occur in 48 hours and can be evaluated and analyzed quickly with a desk-type programmed calculator. Another method was developed for the rapid detection of root-absorbed growth regulators in woody plants involving hydroponic and soil-drench techniques. Single-shoot privet plants are used to facilitate height-growth measurements; uniform growth is obtained in a controlled environment; and the growth inhibitor is introduced directly into the root medium. Significant growth inhibition can be obtained in 1 week using nutrient solution as a medium and in 2 weeks when applied as a soil drench. (J. P. Sterrett, Frederick, MD)

Technologies have been developed for providing controlled release of pesticides through encapsulation in a starch matrix. This technology is applicable to a broad range of pesticides. In greenhouse and limited field research, encapsulated formulations containing highly volatile thiocarbamates, provided control of weeds for up to three times longer than emulsifiable concentrate formulations of carbamates used in a conventional manner. (W. M. Doane and B. S. Shasha, Peoria, IL)

Procedures were developed to extract material possessing brassin plant growth promoting activity from rape pollen. The activity was concentrated and inactive material removed from crude extracts using two-phase solvent partitioning systems. Further purification was accomplished using a series of

chromatographic techniques to afford small amounts of highly active, but as yet unidentified, material. During the course of the separations, a series of compounds closely associated with the active components, but themselves biologically inactive, were isolated. They were found to be six-glucosyl esters of various long chain fatty acids. (M. D. Grove, Peoria, IL)

Technological Objective 2: New and improved knowledge of the nature, behavior, and fate of agricultural chemicals in soils that influence the performance of pesticides and growth-modifying chemicals and their safety to crops, soils, and nontarget organisms in the environment.

Bound residue research with dinitroaniline herbicides has shown some uptake, probably as metabolites, into soybeans. Measurement of bioavailability is significantly affected by prior extraction of soil with organic solvents; i.e., the necessary pre-extraction itself retarded soybean growth. The relative mobility in soils has been measured for some newer pesticides such as oxadiazon, phosalone, TPTH, phentoate, and other compounds of environmental interest such as PCB's and nitrosoatrazine. (C. S. Helling, Beltsville, MD)

A number of herbicides and herbicide impurities have been examined in aquatic ecosystems. The herbicides examined included simazine, 2,4,5-T, trifluralin, diuron, endothall, atrazine, cacodylic acid, and MSMA. The impurities examined were TCDD and hexachlorobenzene. None of the herbicides examined thus far show any tendency to accumulate in fish. (A. R. Isensee, Beltsville, MD)

Research on the fate and behavior of natural and synthetic pyrethroids in soils and aquatic systems indicate that pyrethroids are among the most extensively biodegradable insecticides presently available, and are the most promising insecticides to replace some of the chlorinated hydrocarbons. Soil degradation and metabolism of PCNB and PCP occurs most readily by reductive processes in anaerobic flooded soils. Both stimulatory and inhibitory effects of feedlot wastes and sewage sludge on biodegradation and persistence of 12 pesticides, including herbicides and fungicides, have been observed. (D. D. Kaufman, Beltsville, MD)

Extensive research has been conducted on the fate and behavior of the dinitroaniline herbicides in soils and aquatic systems. These herbicides represent one of the newest and largest classes of weed killers on the market. Soil studies showed that butralin, trifluralin, dinitramine, profluralin, fluchloralin, and chloridine do not form significant amounts of metabolites in soils. Binding of these herbicides to soil components is a significant reaction. In aquatic microecosystems, fish did not exhibit a tendency to accumulate these herbicides from water. (P. C. Kearney, Beltsville, MD)

Research was conducted on the fate and behavior of several arsenicals in soils, wheat, and aquatic systems. The arsenical herbicides are important in the production of several crops and for noncropland weed control. Soil studies showed that metabolism proceeds in two directions, (1) toward more highly methylated and less toxic compounds, and (2) toward demethylated arsenate. In aquatic studies, MSMA and cacodylic acid were metabolized to arsenate which was incorporated by the aquatic organisms or the sediments. Very little accumulation occurred in aquatic organisms. (E. A. Woolson, Beltsville, MD)



Runoff losses of pesticides (endrin, DDT, toxaphene, trifluralin, linuron, diuron) from flat agricultural land have not exceeded 1 percent of the amount applied. There was a strong dependence of DDT and toxaphene concentration on sediment concentration in runoff from a Mississippi Delta watershed. Most of the DDT and toxaphene loss in runoff occurred during the tillage period (February through mid-July) and not during the pesticide application season (August through October). Degradation of DDT and toxaphene in bottom sediments of a shallow pond appeared to be much more rapid than in the soils from which the sediments were derived. Anaerobic degradation of trifluralin was more rapid than aerobic degradation and occurred only at redox potentials less than 150 millivolts, indicating that more than the mere exclusion of oxygen is required for rapid degradation. (G. H. Willis, Baton Rouge, LA)

Nitralin and trifluralin applied to a field soil dissipated to a low residual level within 3-4 months, even with repeated applications at high rates. This research established that normal rates of nitralin or trifluralin may be applied annually without significant residual phytotoxicity on succeeding crops. Sorption equilibria studies with several herbicides are being used as a basis for developing prediction statements relating directly to herbicide availability in various soils. Metribuzin has been evaluated as to its adsorption equilibria, mobility, and persistence in soil. The studies show that the herbicide is easily desorbed, is quite mobile in soil, and degrades rapidly in soil, with half-life values of 30-40 days. Cooperative studies using a tracer material indicated that a high degree of variation existed in spray deposition on the soil surface as related to conventional soil sampling procedures. Incorporation tillage affected the variation and introduced specific pattern variations. (K. E. Savage, Stoneville, MS)

Technological Objective 3: New and improved knowledge on the mechanisms of entry, movement, activity, selectivity, metabolism, and fate of applied pesticides and growth regulators in relation to their effective action in plants and their safety to subsequent crops and nontarget organisms.

Some herbicides inhibit specific sites of lipid biosynthesis to cause alterations in plant lipid composition. Lipids trap water-insoluble herbicides thereby altering their effectiveness and contributing to selective action of some chemicals. Phytotoxic surfactants alter permeability of plant cell membranes through actions on lipid portions of membranes. Some herbicides alter permeability of cell membranes, apparently by a direct contact action.

Pyridazinone herbicides and their analogs have at least three sites of action related to lipids or organelles rich in lipids and the structure-activity relations for these biochemical actions were determined. They inhibit photosynthesis, inhibit carotene biosynthesis, and alter the fatty acid composition of plant membrane lipids. The chemical alteration of a single membrane fatty acid (linolenic acid) alters plant response to temperature stress. Thus, plants with high membrane linolenic are tolerant to low temperature stress, while plants with low linolenate are tolerant to high temperature stress.

Herbicides inhibiting cell division, frequently described as having a colchicine type of action (blocking polymerization of microtubules required for formation of spindle fibers which separate chromosomes during cell division), were found to accomplish their effects by mechanisms different from that of colchicine.

The herbicide, karbutilate, which is both a phenylurea and alkyl carbamate herbicide by chemical structure, was found to exert herbicidal action as a phenylurea (inhibit photosynthesis) and lack the mechanism of action of its carbamate derivative (inhibit root growth). It was more potent and more specific for the photosynthesis site of action than its phenylurea derivative. (J. L. Hilton, J. B. St. John, and M. N. Christiansen, Beltsville, MD)

Several herbicides were identified that interfere with electron transport and phosphorylation in isolated mitochondria or chloroplasts, or in both organelles. It was found that herbicides that inhibited oxidative phosphorylation in isolated mitochondria also decreased ATP levels in excised plant tissue and intact germinating seeds. Results of research suggest that the phytotoxic action of many herbicides is related to inhibition of, or interference with, the production of ATP energy, the chemical energy that drives all cellular activity. This action results, at the whole plant level, in the inhibition of photosynthesis and respiration. Many herbicides interfere only with photosynthesis, a process unique to green plants. Hence, developers of herbicides that affect only this process market compounds that are very safe to man and animals. Based largely on results reported from these structure-activity studies with isolated chloroplasts, many industrial organizations routinely evaluate herbicides against reactions mediated by isolated chloroplasts. (D. E. Moreland, Raleigh, NC)

Maintained a plant tissue culture facility which is used by the scientists in the Plant Science Research group for studies on the metabolism of agricultural chemicals. Determined tolerance levels and effects of organic solvents, hydroxylated metabolites of chlorpropham, and other agricultural chemicals in tissue cultures. Established cell suspensions of okra and cotton for use in metabolism studies. Determined that yellow nutsedge roots are microscopically damaged to a greater extent through cotton roots by an experimental herbicide. Yellow nutsedge plants do not recover after treatment whereas cotton plants do. This helps to explain some of the differences in the response of these two plants to the herbicide. Compared ultrastructural effects of an experimental herbicide on wild oat and wheat. The same compound was found to damage cell suspensions of wheat in vitro at the ultrastructural level. These effects were compared to the process of normal senescence. Some of the responses were similar and some were different from normal senescence. (D. G. Davis, Fargo, ND)

Basic research on behavior and fate of maleic hydrazide in tobacco showed this herbicide is not converted to hydrazine. We have continued to develop a body of research information on the bioavailability of terminal pesticide residues in plants. We developed new techniques and research approaches for investigating the behavior and fate of agricultural chemicals in plants. The results of this research have increased confidence in the safe use of herbicides for weed control. It has also sustained the use of maleic hydrazide for effective tobacco production and helped to maintain our tobacco export market. Basic research findings have resulted in the discovery of new metabolic pathways in higher plants. These discoveries have had a broad impact in the areas of plant biochemistry and herbicide metabolism, selectivity, interactions and mechanism of action in plants, and safety to the general public and the environment. This research has also established principles that aid in the discovery of new, highly specific, selective, and safe herbicides. (D. S. Frear, Fargo, ND)

The distribution and fate of the herbicide diphenamid in pepper, cotton, okra, tobacco, peanut, and soybean were determined. Discovered new persistent conjugates of this herbicide in soybean, cotton, and tobacco. The new metabolites discovered show that the fate of the herbicide is distinctly different in different resistant plant species, and show that resistance to injury from this herbicide is achieved by more than one detoxification pathway. Results of this research support the registration of pesticides and reassures the general public on their safety in the environment. (R. H. Hodgson, Fargo, ND)

Research on the metabolism of atrazine in sorghum was completed. As a result, our knowledge of the metabolism of atrazine is more complete than that of most other herbicides that undergo complex metabolism in a higher plant. Fluorodifen was shown to be metabolized in peanuts by a process somewhat similar to that of atrazine in sorghum. A metabolism study on the behavior and fate of perfluidone in peanuts was completed. Perfluidone is a new herbicide which is very effective in nutsedge control. Three herbicides, CDAA, propachlor and fluorodifen, were shown to be rapidly metabolized and excreted in the rat. The primary route of metabolism was shown to be similar to that observed in plants. An important fungicide



(PCNB, terraclor) is now under review in EPA. It was synthesized in radioactive form and shown to be rapidly metabolized in peanuts. (G. L. Lamoureux, Fargo, ND)

Separation and characterization methods for nonionic detergents were developed. These techniques were used to provide reference materials for evaluating progress in the synthesis of  $^{14}\text{C}$ -tagged materials. The structures of several pesticide metabolites were assigned by using high resolution nuclear magnetic resonance analyses and ancillary shift-reagent techniques. The penetration of certain pesticides and water through isolated plant leaf cuticles was studied. The low permeation rates observed were consistent with results from other studies. (G. E. Stolzenberg, Fargo, ND)

Synthesized a series of nonionic surface active agents (Triton X series and Tergitol TMN series) containing a radioactive tag ( $^{14}\text{C}$ ) at a specific position in the molecule in high specific activity (10 mCi/mmol). Since by weight as much surfactant is being applied as active pesticide in the control of undesired weeds and insects, the determination of their environmental fate is very important. Very little is known about the fate of surfactants in plants and animals. Prior to the synthesis of these materials, thorough studies of the metabolic fate of surface active agents in plants and animals had not been considered. Currently in this laboratory, the metabolic fate of these surfactants are being investigated in both plants and animals. (F. S. Tanka, Fargo, ND)

Herbicides such as atrazine and fluorodifen are readily absorbed by plants but do not remain in their original chemical form in plants for very long. Plants do not eliminate the chemicals from their system, but convert them to non-phytotoxic, immobile forms which remain in the plants. The conversion of chemicals to non-toxic forms is an active natural defense mechanism found in plants resistant to the chemical. A very important and subtle difference in the conversion of a wild oat herbicide to non-toxic forms exists between the two closely related species, wild oat and wheat. This difference makes it possible to kill wild oat but not wheat. These research accomplishments have: (1) contributed to the development and registration of newer herbicides in specific classes of chemicals; (2) aided regulatory agencies in establishing finite tolerances of residues in food and feed crops; (3) has advanced knowledge on the selective action of pesticides which can be used for developing better methods for evaluating candidate pesticides; and (4) has elucidated basic biochemical mechanisms for selectivity which may lead to designing more effective and safer pesticides. (R. H. Shimabukuro, Fargo, ND)

Technological Objective 4: Develop new information on natural bio-constituents and related synthetic compounds that control physiological and biochemical processes for the development of chemicals to modify plant structure and processes.

Germination is ascribed to the balance between the "expansive force" of the embryo and the mechanical constraints of the endosperm tissue. Current studies on the physio-chemical nature of the "expansive force" suggest osmotically active solutes are derived by enzyme activities. Esterase has been identified as one of the components of the extra-embryonic fluid. These findings raise important questions concerning the significance of enzyme activation and de novo protein synthesis in the control of seed dormancy and germination. Although the embryo contains stable messenger RNA's, additional transcripts are formed with the onset of germination. Following imbibition, at least, four transcripts are synthesized by the soybean embryo. (G. R. Chandra, Beltsville, MD)

In studies on adventitious root formation with promoters and inhibitors of the root initiation process, a control mechanism for root initiation was discovered in plants. Cytokinins, both natural and synthetic, are strong inhibitors of the process. More recently camptothecin, a natural selective growth inhibitor, proved to be as strong as the cytokinins in inhibiting root initiation. With a newly discovered hormone in rape pollen, increased overall growth and fruitfulness were obtained in crop plants such as barley, beans, lettuce, potato, and soybean planted in the greenhouse. Leaf area and fresh and dry weight were increased in some crop plants when the hormone was applied to the seed or during early plant development. (L. E. Gregory, Beltsville, MD)

Since the discovery of brassins (a new group of growth substances): (a) production methods have been devised to isolate them on a pilot plant scale; (b) they have been characterized as lipid substances, some of which are attached to sugars; (c) new purification methods have been developed using various techniques such as high performance liquid chromatography; (d) the split internode response in the bean second internode bioassay has been used as a measure for a high degree of brassin purity; (e) different type growth responses have been observed in intact plants and isolated plant parts; (f) increases in vegetative growth and yield have been obtained in crops and fruits, e.g., lettuce, tomato, corn, soybean, and barley in greenhouse experiments. (N. Mandava, Beltsville, MD)

The ethylene releasing agent, (2-chloroethyl) phosphonic acid (ethephon) has been registered for use as an aid for harvesting and curing flue-cured tobacco. Efficiency in use of labor and curing fuel will be obtained as a consequence of this research. A dinitroaniline related compound has been registered by EPA for the control of sucker growth on tobacco, based partially on results from cooperative studies at State experiment stations. Another growth inhibitor can therefore be used to inhibit tobacco suckers, which is important due to high residue levels resulting from some currently used formulations.

Cooperative field experiments were conducted in Brazil, Puerto Rico, and at 10 U.S. locations to evaluate the effects of brassins (a natural biologically active complex from rape pollen) on yields of soybean and barley. All experiments were designed to evaluate the response of large and small seed to several levels of brassin. Applied brassin had no apparent significant effect on seed yield but plants from large seed tended to produce larger yields than plants from small seed in a number of instances. (G. L. Steffens, Beltsville, MD)

Several apparently new biologically active plant extracts are in various stages of development. Brassin, an extract of as yet unknown chemical identity, was shown to be a unique material in terms of biological activity and should be a useful tool to further our understanding of plant growth and development as the material is accurately identified. Camptothecin has been isolated, purified, and identified. Current data indicate that, in terms of the mode of action, it is a new type plant inhibitor. The mode of action of benthocarb, a herbicide for control of weeds in rice fields, was suggested on the basis of a morphological and histological study. (J. F. Worley, Beltsville, MD)



Technological Objective 5: Improved technology for documenting, storing, and retrieving research information on evaluation of candidate pesticides and growth regulators, and new uses for established chemicals including their effects on target and nontarget organisms and for their nature, behavior, and fate in all aspects of the environment.

The chemical records on 31,000 herbicide-evaluated compounds at Frederick, MD, have been used to retrieve computer-verified chemical information on some 2,700 matched structures in a file of 8,200 chemicals evaluated for plant growth regulator effects at Beltsville, MD. The substructure-searching program on the Frederick data base also was used to make 6,000 representative searches, providing summary data and guidance for users of the eventual ARS data base. The chemical-biological information in these 31,000 Frederick records has been incorporated into the ARS system. Improvements in the chemical notations are being provided through automated routines that convert old records into new notations having sharper structure-searching and activity-correlating features. About 30 percent of the biological response data and information in the file of 8,200 Beltsville compounds also has been processed and entered into the ARS data base.

The Wiswesser notations are being used internationally to provide economic computerized structure descriptions in related files such as the British Crop Protection's Pesticide Manual, the WSSA's Herbicide Handbook, the Entomological Society of America's Pesticide Index (here with a WLN index), and NIOSH's Registry of Toxic Effects of Chemical Substances. Early in 1977 Chemical Abstracts Service will publish a Parent Compound Handbook with WLN (Wiswesser Line Notation) entries, covering the most challenging of all chemical collections: all known ring systems, in terms of more than 38,000 ring parents, and some 1,700 cyclic and acyclic stereoparents (like the gibberellins). The name, formula, and ring-structure indexes will be complemented by a WLN index, to provide new searching and correlating pathways. Thus these internationally standardized WLN descriptions, used since 1967 by the Institute for Scientific Information to report all new compounds, give ARS scientists a powerful new tool for searching the chemical world literature. (W. J. Wiswesser and R. A. Creager, Frederick, MD)

### III OTHER SIGNIFICANT ACCOMPLISHMENTS

#### 1. 1976 Program Review and Report for NRP 20290.

Nineteen criteria were used to analyze and evaluate the research programs of all ARS scientists who contribute to NRP 20290. This report, entitled "ARS-National Research Program (NRP) 20290, Agricultural Chemicals Technology for Crops Protection and Modification," March 22, 1977, 175 pages, was distributed to all scientists, technical advisors, line managers, and administrators responsible for this research program. It contains a thorough spectrum of information that may be used to judge the productivity, needs, and benefits of this program.

#### 2. Publications.

A complete list of publications is contained in the Program Review and Report for NRP 20290 cited in 1. above. The 20 scientists who contribute directly to NRP 20290 published 90 scientific papers and 58 abstracts in more than 10 scientific periodicals during the past year. Thus the average was 4.5 scientific papers and 2.9 abstracts per scientist—excellent evidence of productivity.

#### 3. Research Planning Conferences and Workshops.

ARS scientists who contribute to NRP 20290 organized and participated in several research planning conferences, workshops, and program reviews during the past year. These included:

a. Weed research planning conference in soybeans, Tifton, GA, September 20-21, 1976.

b. Research planning conference on development of Colletotrichum gloeosporioides for control of northern jointvetch in rice. ARS-SAES-The Upjohn Chemical Company, Beltsville, Maryland, April 1, 1976.

c. Research planning conference on controlled release technology for pesticides, Urbana, Illinois, November 17, 1976.

d. Allelopathy research planning conference, State College, Mississippi, March 15-16, 1977.

e. Scientists who contribute to this NRP have also participated in other workshops, research planning conferences, and reviews on crop production efficiency research, and seminars, symposiums, and scientific conferences on behavior, fate, and effects of pesticides and other agricultural chemicals on the environment.

#### 4. Preparation of NRP 20290.

More than 15 ARS scientists contributed to the writing of NRP 20290 in 1975 and 1976. This provided an opportunity for most of the ARS scientists who conduct research in this field to contribute to the organization and composition or review of this national research program.

NRP Annual Report  
FY 1976

NRP 20300 IMPROVED EQUIPMENT AND TECHNIQUES FOR CONTROLLING CROP PESTS,  
TO INCREASE PRODUCTION, REDUCE ENERGY INPUTS,  
AND PROTECT THE ENVIRONMENT

TECHNOLOGICAL OBJECTIVES

- 1 To develop equipment and techniques to increase the efficiency and safety of chemical pesticide applications.
- 2 To develop equipment and techniques to increase efficiency and effectiveness of nonchemical control of pests.
- 3 To develop new and improved equipment and techniques for operational pest management systems.

NRP Contact: W. G. Lovely

PAC Contact: D. T. Black

RESEARCH LOCATIONS

1109	Beltsville, Maryland	7302	College Station, Texas
3302	West Lafayette, Indiana	7402	Stoneville, Mississippi
3307	Wooster, Ohio	7502	Mississippi State, MS.
3402	Columbia, Missouri	7602	Gainesville, Florida
3408	Ames, Iowa	7702	Tifton, Georgia
5502	Tucson, Arizona	7706	Byron, Georgia
5805	Yakima, Washington	7803	Oxford, North Carolina



National Research Program Annual Report 20300

IMPROVED EQUIPMENT AND TECHNIQUES FOR CONTROLLING CROP PESTS,  
TO INCREASE PRODUCTION, REDUCE ENERGY INPUTS,  
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Technological Objective III.1: Develop equipment and techniques to increase the efficiency and safety of chemical pesticide applications

Chemical pesticides continue to play an important role in controlling pests. Under some conditions less than 30 percent of the applied chemicals reach the intended target. The performance of chemicals depends on the application equipment and the operational procedures used by farmers and custom applicators. Controlling drift and protecting the environment have imposed serious constraints on the application of chemical pesticides. Fossil fuel use in the development and application of chemical pesticides demands greater precision in application equipment and techniques. The current program is aimed at solving some of these problems. Examples of recent progress follow:

Beltsville, Maryland: The droplet-size distribution of spray was measured systematically throughout the entire spray cone of hollow cone nozzles and solid cone nozzles. The results show that there is considerable variation in the drop size at various points in the spray cone, as has been conjectured in the literature, but not previously measured. The measurements taken were tested for consistency with previous theory by averaging the drop size of the entire spray. In doing so it was found that the mean droplet size was closely proportional to (pressure)<sup>-1/3</sup>, which is predicted from simple theory and shown experimentally earlier on this project using other methods of drop measurement.

Commercial aerosol dispensers were used for releasing insecticide (d-phenthrin) in closed cabins of three sizes of commercial airliners (Boeing models 707, 727-25, and 727-235) in a study of disinsectization, collaborating with the Chemical and Biophysical Control Laboratory. Particle size measurements were made in all tests, and measurements were found to be remarkably consistent from test to test, having a volume mean size of approximately five microns. Aerosol concentration was measured with time after release under the influence of the operating cabin ventilation system. The concentration was found to correlate very well with a perfect mixing ventilation model. The time constant for ventilation in all three aircraft (time required to reach 1/e times original concentration) ranged from 3.9 to 4.1 minutes.

Wooster, Ohio: Both experimental pneumatic and electrically operated systems were fabricated to apply sprays intermittently on plants spaced apart within the rows. Both systems were used to apply insecticides at 10-day intervals on cabbage and pepper plants, and performed satisfactorily except for some problems with the plant sensors when there was considerable variation in plant height. The sensors have been reworked and also components

for sensing with a light beam have been assembled. Several experiments were run in the laboratory to determine the optimum combination of spray-droplet sizes, solution rates per unit area and dosages of miticides needed to control two-spotted, spider mites. Spray droplet sizes were measured in the air blast delivered by three types of orchard sprayers equipped with various atomizers. Fluctuating air velocities delivered by orchard sprayers were recorded at several distances from the outlets and at several locations in tree foliage and in the open. Experimental equipment is being assembled to pump pesticides directly from their shipping containers, mix them in line, and dispense them at rates proportional to ground speed. Minicomputer interfacing and system software were developed and improved to increase processing rates in statistical analysis of micrometeorological data. Computer analyses of corn-canopy atmospheric data indicate that turbulent-velocity spectra follow the Kolmogorov law for frequencies between 0.2 and 0.75 Hz. Thus a universal equilibrium range may exist for plant canopy atmospheric turbulence. Three-dimensional hot-film anemometer measurements of Reynolds stress in both corn and orchard canopies were comparable to similar measurements made by other methods and reported in the literature. Mathematical theory for a fast, two-dimensional Walsh transform image processing algorithm for analyzing canopy-geometry data was further developed. Techniques for performing optical Fourier transforms, correlations, and convolutions of plant canopy sections were developed and used.

Columbia, Missouri: Measurements show AC charging of sprays causes coalescence but the square-wave charging voltage caused a net increase in small droplets for 11 KV and above. A spinning disc droplet separator produced nearly uniform size droplets for all disc speeds, liquids and flow rates tested. Lower rates of pre-emergence herbicides can be used if postemergence herbicides or mechanical cultivations are used. Glyphosate, paraquat and dinoseb were all effective for postemergence weed control when applied with the skid-type sprayer. No soybean injury and excellent weed control resulted when the postemergence herbicides were applied with one fan-type nozzle per row adjusted with the spray-fan parallel, at a distance of 2 to 3 inches above the soil surface and under the leaves of soybeans.

Ames, Iowa: In a 5-year study of seven tillage systems for continuous corn production, adequate weed control was obtained with combinations of preplant, pre-emergence, and postemergence applications of herbicides. The specific herbicide treatment for a particular system was selected based on the weed infestation present. Shifts due to the tillage system and the herbicide program were seen in the predominant weed species. Observations and data collected from these plots by Iowa State University cooperators showed an increase in plant parasitic nematodes as tillage was decreased and an increase in infestation of some leaf diseases as surface plant residue increased.

Yakima, Washington: The efficacy of various spraying systems on both the Pawnee and helicopter for control of several diseases of cherries and beans was evaluated. Helicopter application of Benlate was

satisfactory for control of brown rot on cherries while airplane application of several fungicides resulted in good spray coverage for control of white mold in beans.

The deposition of 2,4-D applied from various spraying systems by aircraft was compared. These studies will assist in resolving unique problems with 2,4-D transport in the Pacific Northwest.

A double-spray system for an airplane was designed, built, and evaluated as a means of allowing direct comparison of different spraying systems. A compressed air system for application of micro-encapsulated formulations of pheromones was developed and used in research on control of the codling moth. An aircraft spray velocity control was modified after testing to overcome a tendency to jam when starting up. The control is now ready for further tests in the aircraft.

A ground spot sprayer was tested in the field. Where there were single plants only, the unit was effective, spraying only that plant. Where plants were grouped in the row, only the first plant in a group would be sprayed. Modifications to resolve this problem are underway.

College Station, Texas: Research on the electrostatic charging of sprays from aircraft revealed that the airframe breaks into corona discharge. This natural phenomena was found to occur in a sequential order at various points on the periphery of the airframe. The location of the discharge point was controlled by imposing a high DC potential on a discharge antenna located above the vertical stabilizer. A study was conducted to select an optimum commercial spray nozzle and induction charging electrode for use in experimental work on aerial spray-charging. A small hollow-cone spray nozzle was more efficient than others tested. The most efficient charging electrode evaluated was a cylinder 1-1/2" I.D. and 1/4" long. Spray application of virus materials to control Heliothis showed that water containing a small amount of adjuvant to increase liquid viscosity, with up to 60 gm of virus/gallon, was found to be a suitable formulation and flat fan nozzle tips along with thorough agitation of the spray material gave excellent control.

Induction charging of uniform spray drops produced by pulsed jets in high-speed airstreams indicated that cylindrical electrodes were more efficient than torroidal electrodes. Increasing the cylinder length and decreasing the distance between the jet breakup point and cylinder wall increase charging efficiency. Electrode wetting and subsequent spraying-off of charged drops having a polarity opposite that of the induction-charged spray limited the net spray charge level.

The maximum spray charge level obtained by induction for malathion spray with an emulsifier added was only about 25 percent of that for tap water. Both oil based and water spray drops were rapidly charged by the ionized-field method.



Stoneville, Mississippi: A promising commercial spray nozzle meters the spray stream through a thin disc orifice with a series of 200 micron holes at 5 to 15 psi. This nozzle produces a series of individual streams that are broken into individual drops by excitation through an electromagnetostriuctive device. A nickel core electromagnet is attached perpendicular to the nozzle and AC voltage is used to impart cyclic pulses to the streams from the orifice. The stream nozzle was not as efficient as conventional nozzles in controlling small weeds in the post-emergence field studies in 1974 and 1975. These tests indicated (1) the lower limit of orifice holes is 200 microns, (2) spray was easier to direct to a specific target with the stream-nozzle and (3) the nozzle may have application on special equipment such as recovery sprayers.

A two-row sprayer was constructed to allow a spray pattern to be directed horizontally across the row profile on small weeds. Spray material not deposited on weeds and crop was collected in a trap across the row and returned to the tank. Although 70 percent of the total spray delivered from the sprayer was recovered, weed control was inadequate because of poor coverage. Young soybeans (8 inches tall) were injured more severely by applications from the recycling sprayer than by a regular directed sprayer.

The spray system utilizing multiorifice solid-stream nozzles with an exciter system was compared to conventional narrow-angle nozzles for effectiveness in applying glyphosate for johnsongrass control in soybeans with the recirculating sprayer. The solid stream nozzles provided better coverage. Glyphosate at 0.56 to 2.24 kg/ha was equally effective for johnsongrass control with the solid stream and conventional nozzles. Also, there was no difference in soybean injury following glyphosate treatment as affected by use of the solid stream and conventional nozzles. Glyphosate applied with only one or two nozzles per row was slightly more toxic to soybeans and johnsongrass than treatments applied with three to four nozzles. The use of a long chain polymer (Low-Drift or Nalcontrol) in spray solutions of glyphosate applied in the recirculating sprayer reduced toxicity to soybeans without affecting johnsongrass control.

Mississippi State, Mississippi: A single equation was theoretically developed for predicting boll weevil mortality from insecticide applications. The equation combines the concepts of probit analysis ( $LD_{50}$  and slope values), the insecticide application rate, the insecticide decay rate, and insect assimilation rate to predict percent mortality of a population of insects versus time for insects exposed to the treated crop at various times after spraying. Available data were used to show the utility of this concept. This equation is being combined into our population dynamics model for methyl parathion, guthion, or malathion insecticide applications.

Gainesville, Florida: Measurement of the droplet-size distribution of insecticidal aerosols is important in evaluating the performance of new or improved equipment and in studying the effectiveness of

various chemical formulations. Techniques have been developed to obtain automatic size distribution measurements of malathion aerosols (10 to 35  $\mu$  VMD) using a Coulter Counter System. Samples of aerosols from ground equipment were collected by settlement into a compatible liquid. Volume median diameters determined by the Coulter technique were in close agreement with those determined by microscopic measurements of droplets on teflon slides.

Tifton, Georgia: A sprayer was designed and built for injecting non-miscible pesticides into the spray diluent concurrently with spraying. The liquid insecticide was injected into the system on the intake side of a pump. This sprayer was field tested with conventional sprayer, a ULV sprayer, a ULV sprayer with recycled air, and a hollow-cone nozzle. All the experimental equipment used in these tests, resulted in equal or better insect control than conventional equipment.

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IMPROVED EQUIPMENT AND TECHNIQUES FOR CONTROLLING CROP PESTS,  
TO INCREASE PRODUCTION, REDUCE ENERGY INPUTS,  
AND PROTECT THE ENVIRONMENT

Technological Objective III.2: Develop equipment and techniques to increase efficiency and effectiveness of nonchemical control of pests

The development of equipment and techniques to supplement or provide alternatives to the use of chemical pesticides is needed to reduce environmental contamination and to improve pest control. The use of mechanical methods, physical methods, biological methods, and mass insect rearing to control pests has been limited because of the lack of research effort on the development of equipment and techniques. Insect monitoring systems and mass rearing technology need to be developed. The present research effort is aimed at solutions to some of these problems. Some examples of progress follow:

Tucson, Arizona: Data on bioclimate, and the development, longevity, fecundity, and mortality of eight species of cotton pests in southern Arizona and five species of predators associated with the pests have been accumulated. The prey accepted and prey preferred, the searching capability, and the sites on the cotton plant that may be penetrated by five species of predators have been determined in the laboratory. Data have been assembled for the development of a cotton plant model for southwestern irrigated conditions using a modification of the SIMCOT or GOSSYM model.

Yakima, Washington: An instrument for measuring insect activity was designed and built. After initial testing, modifications in sensors and circuits resulted in reproducible results. This instrument is satisfactory for measuring differences in activity of individuals of different strains of insects.

College Station, Texas: Mathematical Modeling -- A theoretical model (SPERM) was developed which describes in detail the known physiological, behavioral, and environmental influences on the response of male cabbage loopers to a natural or synthetic pheromone source. Results of simulations appear realistic when related to catches of moths in electrical grid traps baited with synthetic pheromone and to research reported by other scientists. Electrical grid traps baited with the synthetic pheromone of the tobacco budworm (Virelure) show promise for further development as a sampling and/or monitoring tool for the tobacco budworm. The grid pheromone trap with Virelure is apparently quite efficient early in the season and again later in the season, i.e. during periods of lower night time temperatures and low population densities. Peak moth catches were out of phase with peak catches in light traps and tended to follow peak egg lay in cotton by about seven days. Need for improved pheromone dispensing system was revealed by analysis of catch

data in relation to time duration of lure exposure which showed a 50 percent reduction in effectiveness after two days of use. Similar analysis with "Looplure" formulations used in previous studies with the cabbage looper indicates 50 percent reduction after seven days. Grids designed for work with the boll weevil have proven to perform satisfactorily for evaluating trapping efficiency of commonly used pheromone traps and are adaptable for work with whole plants as attractants. Color measurements of bollworm moths with a modified commercial colorimeter elicited data essential to the preparation of specifications for a colorimeter of custom design. Major special requirement is small (3 mm or less) aperture viewing area of study of specific locations on wings and/or body of moth. Techniques were developed for mounting and handling individual wings which gave acceptable capability for reproducing readings.

Stoneville, Mississippi: Values for certain life-cycle parameters were determined for a lab and field-collected strain of Heliothis zea reared under constant and fluctuating temperature with and without light. Continuous darkness produced the largest pupae for both strains. Time from infestation to pupation and to adult emergence was shortest for insects from both strains when reared under constant temperature with light and under fluctuating temperature with continuous darkness. However, field-strain insects on the average were larger, had shorter larval periods, and produced adults that emerged sooner under fluctuating temperatures compared to constant temperature. Mated lab- and field-strain females averaged 2.1 and 1.1 spermatophores, respectively, with few differences between treatment regimes. Egg production varied between generations for the lab strain and most eggs were laid 1 to 4 days after mating. Mating by the field strain moths was satisfactory only under constant temperature with light; egg production increased as mating rate increased. Most eggs laid by field-strain females were deposited 5 to 8 days after mating. Lab-strain females, under all experimental regimes, laid more eggs than field-strain females.

Mississippi State, Mississippi: A pheromone trap model was completed for simulating boll weevil trapping for low populations as affected by insect behavior and trap density. Based on trap catches, the model was used to estimate the remaining population level in the field. When compared with an independent estimate of the boll weevil population in the field, estimates from this model were low. A sensitivity analysis identified several factors needing further study.

A system was developed to mechanically harvest weevil eggs from food pellets. The unit recovered between 98 to 99 percent of the eggs in the food pellets and the harvested eggs had hatch numbers comparable to those which were hand harvested. The equipment in the system was capable of processing one million pellets with 6 man hours of labor. Hand method of processing this number of pellets requires 75 man hours of labor. The machine harvested eggs require only 15 percent as much salt solution to clean the harvested eggs as the ~~hand~~ method.



An automatic valve control system to replace the manually operated valves on the pellet making machine was developed, installed and tested. The system worked satisfactorily and reduced the labor required to operate the machine by 55 to 60 percent.

Tests comparing formed plastic trays with petri dishes as a container for rearing weevils showed the trays gave yields equally as high as the petri dishes. Trays cost approximately 30 to 35 percent as much as petri dishes. Results from tests to evaluate the location of emergence traps in an emergence room showed the three locations studied -- ceiling, side wall at top, and side wall near the floor, had little effect on the number of weevils emerged or trapped.

Gainesville, Florida: Sound is an important communication medium for the plum curculio, Conotrachelus nenuphar (Herbst).

Four types of sound produced by this beetle have been recorded, analyzed, and correlated with specific behavioral activities. These activities are recognition, territoriality, defense and mating. Each of these sounds is different in its waveform structure, frequency content, and pulse information.

The signalling sound of the male Caribbean fruit fly, Anastrepha suspensa (Loew), was recorded and analyzed for normal laboratory reared flies, irradiated flies, and flies that had methanamine mandelate added to their larval diet. There was a spectral line that appeared in the sounds of normal flies that did not appear in the sounds of treated flies.

Data from a six-panel hexagonally arranged electric grid trap located, near soybean fields and baited with synthetic pheromone, revealed that soybean loopers are equally attracted during average wind speed conditions ranging from approximately 0.2 - 1.0 m/s, but respond less with the wind speed below or above this range. Significantly more looper moths approached the pheromone from the leeward side. Effects of wind speed were small compared to night-to-night variations.

The CO<sub>2</sub> production of 1 to 3-day old cabbage looper adults from 5th instar larvae and pupae collected in the field indicated approximately twice the amount of activity over a 24-hour period as did laboratory adults of the same age that had been continuously colonized for four years. CO<sub>2</sub> production of almond moths revealed that their nocturnal activity is strongly inhibited by total darkness, moderately inhibited by a 1 pw/cm<sup>2</sup> radiation intensity (ultraviolet or green), but not inhibited by 15 to 2500 pw/cm<sup>2</sup> intensities. Males tend to be most active in the late diurnal and early nocturnal phases while female activity begins later and persists throughout the nocturnal phase. With 1 pw/cm<sup>2</sup> diurnal light and a dark nocturnal phase the majority of activity occurred during the diurnal phase and only slight activity during the nocturnal phase.

Tests were conducted to determine whether the almond moth is attracted to radiation from green and black light fluorescent lamps. Collections of moths in suction traps appeared to be more dependent upon background radiation for

flight than upon attraction to lamps mounted on the traps. In laboratory rooms collections in traps to which a radiation source was attached were statistically the same as those in traps when the radiation source was located on the opposite side of the laboratory room. A 100-fold increase in radiation intensity caused no significant differences in collection. A slight attraction of female moths to black light radiation was shown.

When testing with cabbage looper moths in the laboratory rooms under conditions similar to those when testing with almond moths, it was found that within 24 hours about 85 percent more moths were caught in the trap with black light lamp attached than when it was remote. About 38 percent more beet armyworms were caught under these same conditions.

In field tests the electrocutor grid traps operated with 4 ma. transformers and baited with synthetic sex pheromones of the lesser peachtree borer or peachtree borer were found to be more effective and efficient in capturing males than sticky traps baited with either pheromone. A portable 6" x 12" high cylindrical grid with 1/2" electrode spacing captured equal numbers of moths as the 12" diameter x 18" high grids with 1/2" and 1/4" electrode spacings.

Research on control of two species of mosquitoes, house flies, and stable flies has developed nonchemical methods of control including both the release of sterile insects and biological control agents which may be useful if integrated with other methods of control such as chemicals. At the same time basic data on life history parameters of these insects have been developed for field and laboratory populations. A computer modeling procedure for simulating density trends as they occur in natural populations has been developed for these species. It is now possible to compare the effectiveness of nonchemical and chemical methods of control by computer simulation when these methods are used singly or in various combinations and patterns. Although such simulations do not take the place of field trials, they provide input in planning and designing control strategies.

Improved methods of mass-producing mosquitoes have been developed. These improvements include development of techniques for using thermostatically controlled electric heat cables to maintain water temperature in shelved rearing pans and development of procedures to set dried mosquito eggs in the rearing pans to improve uniformity of the initial sets. These techniques, along with diet improvements, have resulted in a 100 percent increase in rearing efficiency.

Tifton, Georgia: Equipment developed for mechanizing corn earworm (H. zea) rearing has been modified for use in boll weevil (Anthonomus grandis) rearing. Modifications include a conversion of the diet filler; a cooling tunnel designed, fabricated, and tested for cooling the diet rapidly to accommodate development of a new egging system; and development of a method of placing sand upon the egged trays. Plastic rearing trays are formed, filled with diet, cooled, egged, sanded, covered, and sheared in a continuous

in-line operation at the rate of about 300 trays per hour. Use of this equipment reduces the cost of rearing containers by about 75 percent. Additional savings are expected by eliminating the need for separate functions to fill trays, cool, egg, and sand.

Byron, Georgia: Sampling of the hickory shuckworm population in a pecan orchard with a 22-W BL trap was used to time shuckworm sprays as opposed to calendar timing. When as many as 6 moths were captured during a night from the time nutlets appeared until shuck split, an application of Zolone was made. Applications were not made at less than 2-week intervals. Three applications were made in the calendar timed orchard at 2-week intervals. Shuck infestation levels were 3, 14, and 60 percent respectively for BL trap timing, calendar timing, and check orchard. A test conducted to compare the effectiveness of 15-W survey BL traps operated by an inverter from a 12-V d.c. power source and from a 120-V a.c. power source indicated no apparent difference in total weight of insects captured. It appears that greater numbers of beetles are attracted to the trap when operated by the inverter. Tests show that a 22-W BL lamp mounted horizontally in a 10" tractor gas funnel with a 1-5/16" diameter throat to be more effective for capturing shuckworms than either a 15-W BL lamp mounted vertically or a 22-W BL lamp mounted horizontally over an 18" funnel with a 2" diameter throat. Early tests indicate that modifications made to a basic inverter circuit have increased the output of UV energy with lower power consumption from the battery than readily available inverters for BL traps.

Oxford, North Carolina: Data from 62 sampling blacklight-type traps confirm that normal populations of tobacco and tomato hornworm populations are as large inside as outside the former large integrated test area. However, levels on both sides remain quite low. Electrocutor grids baited with virgin females (VF) or artificial pheromone were found far superior to other type traps for establishing seasonal and nightly activity curves for native adult budworms. Bait of 20 live VF attracted almost 3 times as many males as did 1/2-inch<sup>2</sup> strip of artificial pheromone (Virelure). Although Virelure attracted males earlier in the night, VF attraction was dominant when both were present in field or cage tests. Capture of tobacco budworm males was improved when VF as bait were placed in darkness several hours before nightfall.



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IMPROVED EQUIPMENT AND TECHNIQUES FOR CONTROLLING CROP PESTS,  
TO INCREASE PRODUCTION, REDUCE ENERGY INPUTS,  
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Technological Objective III.3: Develop new and improved equipment and techniques for operational pest management systems

Pest control efficiencies, cost analysis, and energy use analysis of integrated management systems for pest control are not available. Prediction models are needed to evaluate the complicated and numerous interactions between the pest management and production systems. Data acquisitions are needed to collect useable information on pest development, crop development, and environmental factors. The research being conducted is aimed at solving some of these problems. Some examples of recent progress follow:

West Lafayette, Indiana: A battery-powered environmental data acquisition system was installed in a corn field and used to continuously record data. Methods and soft-ware for data processing were perfected to the "cook-book" state; including permanent storage on private disc packs. Data are for correlating insect survey information to environmental factors, for predicting insect growth and development, and for basing simulations. Environmental factors are presently being correlated with adult corn rootworm captures by pheromone baited sticky board traps and to capture of 32 species, mainly carabids, in pit-fall traps. Second year field comparisons of the relative attractiveness of new lamps used for general lighting, showed high pressure sodium lamps to be similar to low pressure sodium, with both significantly less attractive than mercury vapor or blacklight fluorescent lamps.

Weather data recording instruments were installed and maintained for the second year to record data for a Cereal Leaf Beetle Research Pilot Project. Data from a system of survey light traps were released through cooperators to advise farmers where and when insect outbreaks might occur. Literature were reviewed and a weather-based simulation of the life cycle of the Hessian fly written in draft form. Data were taken to calibrate this model. A validated Fordyn-Fortran IV, complicated simulation of the life cycle of the European corn borer, was simplified and translated into GASP IV for more universal acceptance and easier use. A weather-based simulation of the black cutworm's life cycle was written. This draft points to many voids in available information.

Yakima, Washington: The use of infra-red photography for survey and detection of several pathogenic diseases and nutritional disorders of apples and cherries was explored. In British Columbia IR photography did not detect trees infected with little cherry virus before symptoms were visible to the human eye. Nutritional disorders of apple trees were detected.



College Station, Texas: Considerable progress has been made in developing and refining a mathematical model (MOTHZV) to make it operational as a prediction model for predicting timing of Heliothis spp. populations two generations in advance. The model was used in 1975 to predict successfully within two to three days the timing of expected egg lay in cotton year College Station.

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SRP Report

1. Minor Use Pesticides
2. This Special Research Program contributes to the Department's Mission 2, Agricultural Production Efficiency, Mission 3, Agricultural Marketing Efficiency, and Mission 7, Consumer Services and Human Resource Development. The Minor Use Pesticide Special Research Program will contribute to the availability of pesticides for minor and special uses by the agricultural community and assure a continuation of crop and livestock production technology for production, storage, distribution, and marketing of food, feed, seed, and fiber.
3. The Technological Objective for this program is to develop data for use in registration of pesticides for minor crops, minor uses on major crops, and speciality uses.
4. Selected examples of progress. In FY 1976, the program contributed to the development of data for the registration of 42 pesticide use patterns that were in the IR-4 Project ("A National Agricultural Program for Clearances of Pesticides for Minor or Speciality Uses"). These included a wide variety of commodities such as asparagus, birdsfoot trefoil, blueberries, cabbage, carrots, chestnuts, cranberries, cucumbers, forage grasses, hops horses, leafy vegetables, lentils, lettuce, mint, mushrooms, nursery crops, onions, peaches, pecans, raspberries, safflower, small grains, Southern peas, spinach, strawberries, table beets, and tomatoes. These projects are approximately equally divided between disease, insect, and weed pests. Data is being generated to develop information on efficacy, phytotoxicity, and residue.

Of the projects funded in FY 1976, ARS has completed five projects as follows: ronnel to control biting flies on horses; pyrethrins used in greenhouses to control whiteflies as pests of lettuce, tomato, and cucumber; and endosulfan to control rose stem girdler on raspberries.

7. The following locations were involved in the Minor Use Pesticide Research Program in FY 1976: Mesa, AZ; Byron, GA; Tifton, GA; Vincennes, IN; Beltsville, MD; Frederick, MD; Rutgers, NJ; Ithaca, NY; Fargo, ND; Charleston, SC; Kerrville, TX; Weslaco, TX; and Yakima, WA.



Annual SRP Report Pilot Testing of Alternative Methods of Pest Control

INTRODUCTION

The pilot test program provides short-term (2 to 5 years) funding of high-priority research areas in order (1) to develop for critical assessment distinctively new or innovative methods of pest control, and (2) to provide for developmental research needed to take pest control technology from the small-field research phase to practical utilization. This Special Research Program deals with weeds, nematodes, insects, and plant pathogens.

Emphasis is placed on developing practical pest control technology that does not involve sole reliance on broad spectrum pesticides. This technology should reduce the contact of man and other nontarget species with chemical residues. The program develops technologies which industry is not likely to develop without the involvement of public sector research agencies.

The program consists of discrete projects that are selected by peers in the regions reviewed by the National Program Staff Operational Coordination Group and Administrator's Staff Conference members and approved by the Administrator or Associate Administrator.

Two reports are required each year; one being the annual Work Reporting Unit Report and the other being a special report due in December. Since this reporting system was not yet fully implemented, the annual report was prepared from whatever information was available.

## Annual SRP Report

### Area-wide Suppression of the Navel Orangeworm

Principal Investigator: C. E. Curtis

Test sites in Merced County and Kern County, California, were selected to develop a practical system of orchard sanitation, early and rapid harvest, and insecticide use to control the navel orangeworm and the peach twig borer on almonds. Other host plants such as walnuts and peaches were included in winter sanitation operations for removing mummy fruits from trees by mechanical shaking or hand poling. Previous research had established that the mummy fruits remaining on trees permit the pest to overwinter and to infest almonds throughout the subsequent growing season. Removal of the mummy fruit in small acreages is ineffective in controlling the pest, presumably because of its considerable powers of dispersal. The test sites consist of 2,600 acres of almonds plus other host crops in Merced County and 380 acres in Kern County. Similar check areas were established in each county. A total of \$499,705 was allocated to the project over 3 years (fiscal years 1975 through 1977) from the Administrator's Pilot Test Fund. Some support was also obtained from the almond industry. The results from the first year of this 3-year study showed that the integrated program is economically feasible and effective. For example, the alternative system showed a net profit of \$61 per acre in Kern County.

### Suppression of Leaf Roll Disease in Maine Seed Potatoes

Principal Investigator: F. R. Holbrook  
Orono, Maine

Aphid-borne leaf roll virus disease is the most important disease problem facing the Maine potato seed industries. In past years, about 96 percent of fields produced State certified seed, but this has been reduced to 35 percent in recent years. A pilot test (fiscal years 1975 through 1977, \$170,000) to deal with this problem was designed as a large-scale replicated factorial experiment to identify the optimum combination of practices which minimize leaf roll incidence without unduly reducing the number and volume of seed pieces. The treatment variables include (a) susceptible (Russet Burbank) and mildly tolerant (Katahdin) varieties, (b) early and late top-killing, and (c) application of systemic insecticide at planting alone or combined with foliar applications of contact insecticide late in the growing season. These treatments are being applied on both an individual field and on an area-wide basis under relatively light disease pressure in northern Maine and under heavy disease pressure in southern or central Aroostook County.

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Samples of 200 tubers were taken from each plot and entered in the Maine Seed Board Florida Test Program for evaluation of virus content. Aphid populations were unusually low during the 1976 growing season. Nevertheless, the data show that the most important factors in preventing leaf roll disease (in descending order of importance) are (1) area-wide application of systemic insecticides, (2) early destruction of potato vines, (3) varietal tolerance, and (4) foliar application of insecticide. Indeed, the first two factors are far more important than the last two.

### Integrated Control of Pecan Insects

Principal Investigators: C. R. Gentry, J. S. Smith, Jr.,  
and W. L. Tedders  
Byron, Georgia

The hickory shuckworm is a serious pest across the pecan belt; causing losses through "early drop" of pecans. Yellow pecan aphids cause serious losses as a result of the constant drain on the carbohydrate supply of the tree and the interference with photosynthesis by sooty mold which grows on the honeydew. Yellow pecan aphids, black pecan aphids, and mites are often responsible for reduced tree bloom. In addition, black aphids cause premature leaf defoliation in late summer and fall.

Previous work at Byron, Georgia, has shown that four blacklight traps per acre suppress hickory shuckworm infestations to a degree comparable to that obtained by three insecticide sprays. In addition, soil application of the systemic insecticides disulfoton, have been developed which effectively control yellow and black pecan aphids, spider mites, and which have some effect on the serpentine leafminer and pecan spittlebug.

A pilot test (fiscal years 1975 through 1977, \$42,094) is being conducted to determine the practical feasibility of controlling most pecan insects by means of blacklight traps and soil applications of a systemic insecticide soil fumigation to control the pecan weevil, and control of pecan scab and other pecan diseases with fungicides applied at infrequent intervals. An assessment is being made of the effect of the absence of foliage insecticide sprays on the natural enemies of pecan insects. The pilot test is being conducted with the help of University of Georgia extension specialists in a 50-acre commercial orchard near Fort Valley, Georgia. An adjacent 50-acre orchard is being treated with a conventional spray program.

The integrated system has adequately controlled all insects except spittlebugs. However, pecan scab was not adequately controlled by the extended interval spray schedule.



## Annual SRP Report

### Suppression of Peachtree Borer and Lesser Peachtree Borer by Means of Pheromones

Principal Investigator: C. R. Gentry  
Byron, Georgia

Peachtree borers and lesser peachtree borers are the major insect pests of peaches. Growers in the Southeast spend about \$75 per acre per year for insecticide treatments to control these pests.

In recent years, Agricultural Research Service scientists have identified the sex pheromones of these species. Field studies have shown that the pest populations can be suppressed by trapping and by mating disruption using these pheromones.

A pilot test is being initiated (fiscal years 1977 through 1979, \$93,000) to determine whether peach orchards can be protected from these borers by the application of behavioral chemicals.

### Integrated Control of the Citrus Mealybug in Texas

Principal Investigator: W. Hart

The citrus mealybug became a serious pest of Texas grapefruit production in 1970. Insecticides in general have not been effective in controlling this exotic pest. However, past research, primarily in California, has shown that inoculative releases of predators and parasites, control of honeydew feeding ants which protect the pest from its natural enemies, removal of weeds and vines under trees, trimming of skirts and other grove care practices, tend to suppress the pest. A pilot test is being initiated (fiscal years 1977 through 1980, \$234,444) in order to evaluate the practical feasibility of integrating these control methods as an approach to economical control of the pest.

### Control of Rush Skeleton Weed with a Rust Pathogen

Principal Investigators: R. G. Emge and C. H. Kingsolver  
Frederick, Maryland

Rush skeleton weed has spread from its center of origin in the southern USSR to the United States and other continents. That this weed has the potential to usurp crop production in semi-arid regions is demonstrated by the abandonment of farmland in the infested wheat-producing area of

## Annual SRP Report

southeastern Australia. The pest has become a serious threat in the Pacific States. A pilot test was initiated (fiscal years 1977 through 1979, \$90,000) to assess the feasibility of managing this pest with inoculative releases of the rust Puccinia chondrillina.

Five sites in Placer County, California, and one site in El Dorado County, California, were inoculated with the uredospores of an Italian strain. Infection was established at five or six sites. Strains of rust are being selected to suppress resistant clones of the weed which have infested Idaho.

### Management of Plant Parasitic Nematodes With Insect Growth Regulators

Principal Investigator: J. Feldmesser  
Beltsville, Maryland

Agricultural Research Service scientists have found insect growth regulators to be highly active against nematodes in soil drench tests. In fiscal year 1977, a pilot test was initiated (fiscal years 1977 through 1978, \$60,000) to assess the technical feasibility of using insect growth regulators to protect crops from nematodes. The work plan is now being implemented.

### Decreasing Frost Damage to Crops by Suppressing Ice-Nucleation-Active Epiphytes

Principal Investigator: C. D. Upper  
Madison, Wisconsin

Recently, studies have shown that corn, lettuce, beans, tobacco, and tomatoes are not inherently sensitive to frost injury in the range of -2 degrees to -5 degrees C., i.e., temperatures at which radiation frost damage frequently occurs. Rather, these crops are predisposed to frost damage at these temperatures by the presence on their leaves of certain pathogenic and nonpathogenic bacteria. Small-scale studies have shown that frost damage can be reduced by suppressing the populations of ice-nucleation-active epiphytes by means of (a) antibacterial sprays, (b) addition of materials to change the nutritional characteristics of leaf surfaces, and (c) application of competitive bacteria that do not promote ice crystal formation. In fiscal year 1977, a pilot test was initiated, (FY 1977 through 1980, \$169,696) to assess the technical feasibility of protecting corn and tomatoes on a large scale by the above means.

Control of Northern Jointvetch in Rice with a Fungus Disease

Principal Investigators: R. J. Smith and G. E. Templeton  
Stuttgart, Arkansas

In 1969, an endemic anthracnose disease of northern jointvetch incited by the fungus Colletotrichum was discovered in Arkansas. Basic studies established that aqueous spray systems of the fungus spores will control the weed in a growth chamber, greenhouse, and in the field. Environmental conditions which favor the development of the disease were established. Also, the host range was found to exclude domestic crops and certain weeds. Aerial application of the inoculum on rice fields ranging in size from 30 to 40 acres gave good control of northern jointvetch.

A 3-year pilot test was initiated (fiscal years 1975 through 1977, \$225,000) to determine technical and economic feasibility of controlling northern jointvetch in commercial rice fields with the fungus disease. Research was conducted to scale up production, packaging, storage, transportation, formulation, and application of virulent conidial inoculum for commercial rice field treatments. Toxicological studies were undertaken to assess acute oral toxicity, mycotoxin production in molded grain, and respiratory effects of the fungus. Systems and economic analyses were conducted to determine how the bioherbicide fits into a weed control program and to compare costs with other weed control methods.

Aerial applications were made by commercial applicators on nearly 1,000 acres and have given 95 percent to 100 percent control, and there is some carryover of the disease from one year to the next. Certain problems in storing the spores remain to be solved. All studies conducted thus far have given no evidence of hazard to vertebrates.

A Mixture and Rate Controlled Sprayer for Microbial and Chemical Pesticides

Principal Investigators: M. R. Gebhardt and C. E. Goering  
Columbia, Missouri

Microbial pesticides are inherently expensive, and therefore, recommended rates usually are the minimum needed for efficacious pest control. Therefore, errors in application rates caused by faulty equipment design may result in uneven coverage and control failures. In the case of chemical pesticides, such errors can be offset by applying higher than actually needed rates. Research at Columbia, Missouri, has shown that metering principles exist which permit accurate pesticide application irrespective of the ground speed of the sprayer. Positive metering can be accomplished by using both flow and concentration control. Also electronic controls have been devised to instantaneously adjust the mixture to the pest population existing at any point in the field.



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The farm machinery industry has not adopted positive metering because the studies at Columbia have not been carried far enough. Therefore, in fiscal year 1977, a pilot test was initiated (FY 1977 through 1980, \$46,827) to construct a prototype and to demonstrate its practical feasibility with commercial preparations of Bacillus thuringiensis and Baculovirus heliothis.

### Formulations and Delivery Systems to Optimize Field Efficacy of Microbial Insecticides

Principal Investigators: M. R. Gebhardt, D. B. Smith,  
C. M. Ignoffo, and D. L. Hostetten

Microbial pesticides are applied in formulations with equipment designed to apply chemical pesticides. A pilot test was conducted (fiscal years 1975 through 1977, \$221,250) in order to identify optimal combinations of droplet size, droplet density, and concentration needed to control cabbage loopers and bollworms with Bacillus thuringiensis and Baculovirus heliothis. The following has been established:

1. A spinning disc droplet generator is suitable for producing spray droplets of appropriate size ranges.
2. New wettable powder formulations increased the yield of cotton from 15 percent to 114 percent.
3. An adjuvant on treated leaves was found to increase insect feeding by threefold.
4. Spray deposits decrease from the top of the soybean canopy downwards and likewise pest mortality decreases.
5. High pressure or high shear is not detrimental to the activity of Bacillus thuringiensis.
6. Mineral oil/water and keltose are superior spray carriers for Bacillus thuringiensis and polyvinyl alcohol and mineral oil are superior carriers for Baculovirus.
7. The optimum droplet sizes of encapsulated formulations are produced with the smallest orifices and highest pressures.

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Integrated Control of the Dog Fly

Principal Investigators: D. E. Weidhaas, R. S. Patterson,  
and D. F. Williams  
Gainesville, Florida

Dog flies or stable flies cause serious losses to the livestock and tourist industries in the United States as well as throughout the world. Field experiments on dairy farms near Gainesville, Florida, showed that the sterile male method can be used to strongly suppress the pest population when used in conjunction with parasite releases, insecticide treatment, or sanitation.

In fiscal year 1975, a pilot test was initiated (FY 1975 through 1977, \$338,922) on St. Croix to assess the feasibility of using the above techniques to suppress the pest on an area-wide basis.

Excellent progress has been made. The pest has been strongly suppressed on the eastern half of the island, and the prospects for achieving control over the entire island are bright.

Control of the Malarial Vector, Anopheles albimanus, by the Integrated Use of the Sterile Male Technique Cultural Methods and Insecticides

Principal Investigators: D. E. Weidhaas, R. E. Lowe, and  
K. E. Savage  
Gainesville, Florida

Control of malaria in many areas where military personnel are stationed has become more difficult with the extensive development of insecticide resistance in mosquito vectors. Previous studies in an isolated 5-square mile area of El Salvador showed that the vector could be strongly suppressed by reducing larval development and by releasing sterile males.

In fiscal year 1975, a pilot test was initiated (FY 1975 through 1977, \$482,575) in order to determine whether the combined use of insecticides, cultural methods, and releases of sterile males could be used to effectively prevent malaria transmission in a large area (50-square miles).

The large-area experiment requires the release of 300,000 to 500,000 sterile males per day. Methods of mass rearing and destroying females prior to release have been perfected. The experiment is 6 months behind schedule and has now entered its most critical phase.

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Genetic Control of Hessian Fly Population

Principal Investigators: J. E. Foster and R. L. Gallun  
Lafayette, Indiana

Eight biotypes of the Hessian fly have evolved with the capability of attacking cultivars of wheat which previously were resistant to the pest. However, the avirulent trait found in the Great Plains race is dominant over all of the genotypes of virulence. In small field trials, wheat was protected from the virulent races by mass releases of the Great Plains race. A pilot test is being initiated (fiscal years 1977 through 1979, \$164,985) to assess the feasibility of this genetic approach on a practical scale. The first releases will be made during 1977.

Management of Sugarcane Borer Populations through Programmed Releases of a Selective Parasite

Principal Investigators: D. F. Martin, T. E. Summers,  
and R. D. Jackson

The sugarcane borer is a very serious pest of sugar production in Louisiana and somewhat less serious in Florida. The Cuban Fly is one of the more effective parasites of the sugarcane borer in various countries. This parasite was introduced and firmly established in southeastern Louisiana. However, the level of parasitism normally does not exceed 20 percent of the pest population. A "first generation" population model was developed which showed that through programmed releases of laboratory-reared parasites this level of parasitism could be substantially increased. This projection was validated in field tests conducted in Florida in 1973 and 1974. In fiscal year 1975, a pilot test was undertaken (FY 1976 through 1977, \$288,581) in order to evaluate on a large scale the feasibility of rearing and releasing the Cuban fly on several thousand acres. This pilot test served the additional purpose of developing and validating a more refined parasite/host decision model.

The releases made with the assistance of the Animal and Plant Health Inspection Service in Florida showed that the parasite can be used to effectively suppress the pest. Also, early season releases in Louisiana indicated that contrary to prior reports, the parasite can function under the environmental conditions in that State. The Cuban fly has now become established in Florida. The industry is unlikely to adopt this technology so long as the price of sugar remains low.



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Evaluation of the Effect of Large Plantings of Pubescent Wheats in Concentrating the Cereal Leaf Beetle on Susceptible Host Plants

Principal Investigator: R. L. Gallun  
West Lafayette, Indiana

Research has shown that a dense mat of leaf trichomes deters the cereal leaf beetle from ovipositing on wheat in experimental plots of normal size. Several lines of such "resistant" germplasm were released in 1974 and 1975. A pilot test was initiated (fiscal years 1975 through 1978, \$149,112) to determine (1) whether the pest would move out of resistant wheatfields and lay eggs on oats, grasses, and other susceptible hosts and whether susceptible hosts would be overwhelmed by displaced beetles, (2) whether the above mechanism can be used to concentrate the pest population in order to destroy it with parasite releases, and (3) the degree of resistance of the wheats under "no choice" conditions.

About 800 acres of wheat have been planted. The pubescent wheat, Fuzz, was found to have only an intermediate level of tolerance whereas another pubescent wheat, Downy, is virtually immune. The difference in levels of resistance was found to be caused by differences in trichome length. (Previously only trichome density had been thought to be important in conferring resistance.) Effects of growing resistant wheat on pest levels in oat have not yet been established.

Microbial Control of Rangeland Grasshoppers with Nosema locustae

Principal Investigators: J. E. Henry and J. A. Onsager  
Bozeman, Montana

Rangeland grasshoppers are held in check by a cooperative Animal and Plant Health Inspection Service/State spray program in which about 2 million acres are sprayed with insecticide per year. A selective control agent would be desirable so that the natural enemies of the pests would be spared and so that disruption of commercial beekeeping could be avoided. Nosema locustae, a protozoan which infects many grasshopper species, has been shown to have the potential for selectively suppressing grasshoppers. However, in small-plot experiments, the movement of grasshoppers into and out of the treated plot quickly obscures the long-term effects of the pathogen.

In fiscal year 1975, with help from APHIS, a pilot test was initiated (FY 1975 through 1977, \$91,200) in order to evaluate the value of applying

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the spores to 5,000-acre plots in four replicates and to compare grasshopper densities on these plots with those on plots treated with malathion or left untreated.

Grasshopper densities tend to be cyclic over a period of 7 to 10 years. During the last 3 to 5 years of the cycle, population densities may gradually increase to outbreak levels unless artificially interrupted by catastrophic weather, parasites, predators, and several viral, bacterial, fungal, and protozoan diseases. Thus, the pilot test is an attempt to artificially induce an epidemic among grasshoppers without having to endure the 3 to 5 years of ravage that typically precedes a naturally-induced population crash. This pilot test required both an Environmental Impact Statement and a Temporary Exemption from Requirement of a Tolerance.

The test showed that the pathogen, when applied at the rate of 1 billion spores in 1.5 pounds of bran bait per acre, provided effective control. However, the long-term effects could not be accurately assessed because of an area-wide catastrophic outbreak of Entomophthora in 1976. Methods of producing and of storing the Nosema spores were developed. However, no specific action has been taken to register the formulation with the Environmental Protection Agency.

### Development of Kairomones for Increasing the Effectiveness of Entomophagous Insects

The host-searching behavior of parasites and predators is strongly influenced by the odors (kairomones) emitted by the host. The chemical identity of the kairomones in moth scales attached to eggs and to which the parasitic wasps Trichogramma evanescens responds was reported to be tricosane by scientists of the Agricultural Research Service in 1971. A 3-year pilot test was initiated in Tifton, Georgia, in fiscal year 1973 in order to (1) evaluate in field-size tests the practicality of tricosane and other host-seeking stimulants as a tool for control of pest insects egg populations, and (2) to develop practical formulations and procedures for applying these materials, and (3) to determine the usefulness of kairomones in attracting, retaining, and activating search of natural enemies in habitat areas. For the 3-year period FY 1973 through 1975, \$250,000 was committed to this project. During this period, considerable progress was made in using kairomones to (a) markedly increase rates of parasitism in low-level pest populations, (b) retain parasites in treated fields, and (c) condition released parasites not to disperse but to search in those fields in which they were released. Nevertheless, the second objective was not attained. Therefore, an additional \$112,500 was committed for the period FY 1976 through 1977 inclusive. Very favorable results were obtained by using kairomones in making releases of 25,000 to 60,000 Trichogramma per acre to control the

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corn earworm on cotton, corn, and soybeans. Nevertheless, the attainment of objective number 2 by the end of fiscal year 1977 is in question.

### Suppression of Mosquito Vectors of Malaria with a Nematode Parasite

Principal Investigators: H. C. Chapman and J. J. Peterson  
Lake Charles, Louisiana

Mosquitoes are rapidly becoming resistant to insecticides and a recrudescence of malaria is occurring in developing countries. The increase in transmission of malaria directly affects United States military personnel stationed abroad. A nematode parasite has been developed for controlling mosquitoes, and it is likely to be marketed on a small scale in the United States.

In fiscal year 1977, a pilot test was initiated (FY 1977 through 1979, \$222,380) to determine whether this parasite can be used in a developing country to suppress malaria. The study is being initiated at Lake Apastepeque, El Salvador.

### Control of Muscoid Flies with Programmed Releases of a Parasite

Principal Investigators: D. E. Weidhaas, P. B. Morgan,  
R. S. Patterson, and G. C. LaBrecque  
Gainesville, Florida

Houseflies, stable flies and other muscoid flies are serious pests on farms and in cities. The hymenopterous wasp Spalangia endius normally parasitizes 10 percent to 15 percent of these flies in Florida. However, through programmed releases of these wasps, sufficiently high rates of parasitism can be achieved to give excellent fly control.

A pilot test is being initiated (fiscal years 1977 through 1979, \$70,000) to determine whether the parasite can be used as an economical and practical method of fly control for poultry installations. Various parasite release techniques, methods of estimating population levels and computer models to guide release programs will be assessed in the first year. During the second year, the optimal parasite release schedule and recommended insecticidal control programs will be compared on a cost and environmental contamination basis. During the third year, integrated control measures involving the parasite, including poison baits, parasite releases along and in combination with other species of parasites, will be evaluated.



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Suppression of Mosquitoes by a Nematode Parasite in the Northeastern United States

Principal Investigator: W. R. Nickle  
Beltsville, Maryland

Studies by Agricultural Research Service scientists at Lake Charles, Louisiana, demonstrated that the nematode Romanomermis culicivorax may parasitize a high proportion of many species of mosquitoes. A pilot test (fiscal years 1975 through 1977, \$70,000) was conducted to assess the feasibility of using this parasite to control mosquitoes in northeastern United States. Cooperative field studies with the parasite were conducted at more than 20 locations in the northeast. The nematode was found to parasitize a significant proportion of mosquitoes in ponds, to overwinter and "recycle." The Environmental Protection Agency decided that the use of this parasite does not fall within the purview of the Federal Insecticide, Fungicide, and Rodenticide Act. A commercial company has commenced production and formulation of this natural enemy according to specifications used and developed in this pilot test.

Effectiveness of Inoculative Releases of the Imported Aphid Predator *Coccinella septempunctata* in Various Areas of the United States

Principal Investigator: G. W. Angalet  
Newark, Delaware

The most important aphid predator in the Palearctic Region has been introduced and established in northern New Jersey. A highly effective aphid predator is needed throughout the country. In fiscal year 1977, a pilot test was initiated (FY 1977 through 1979, \$67,050) in order to assess the potential usefulness of inoculative releases of the predator to suppress various aphids. Arrangements have been made with cooperators to evaluate the predator against (a) blue alfalfa aphid in New Mexico, (b) pea aphid in New Mexico, Ohio, Georgia, and Iowa, (c) spotted alfalfa aphid in New Mexico, (d) three species of pecan aphids in Georgia, and (e) corn leaf aphid in Ohio and Illinois. Approximately 50,000 living specimens have been collected for shipment to cooperators.

Integrated Control of the Pink Bollworm and Other Cotton Pests in the Southwest

Principal Investigator: T. J. Henneberry  
Phoenix, Arizona

The pink bollworm became established in the southwest during the mid-1960's. The need for heavy use of insecticides against this pest has interfered greatly with the integrated control system that had been implemented against indigenous cotton pests. Also, the action of the pest has in some instances resulted in an increase in levels of aflatoxins in cottonseed.

In recent years, a number of new methods of controlling the pest have begun to emerge including nectariless cotton, late-season chemical termination of fruiting, winter irrigation, and the pheromone for trapping males and disrupting mating. None of these alternative methods appear to be effective alone.

In fiscal year 1976, a pilot test was initiated (FY 1976 through 1978, \$629,800) to develop these individual methods and to combine them into a system for managing these pests.

DPL 16 nectariless cotton was shown to reduce infestation levels of the pink bollworm and, in most cases, to outyield standard cultivars. The experimental plant growth regulator, Penwalt TD1123, was found to be superior to other materials for terminating fruiting (and concomitantly lowering the overwintering pest population) and, as a preconditioner, to enhance defoliation. In 1976, chemical-terminated cotton averaged 100 pounds of lint per acre more than the control, and the nectariless cultivar averaged more than 200 pounds of lint per acre more than the control.

Improved Formulations of Heliothis Virus

Principal Investigator: D. L. Bull  
College Station, Texas

In field evaluations, the Heliothis nuclear polyhedrosis virus has shown promise as a selective control measure for the bollworm and tobacco budworm. Indeed, this virus has been registered by EPA for controlling these pests. However, this virus does not provide adequate levels of suppression to be recommended by extension personnel. One of the principle problems appears to be lack of persistence of the applied virus under field conditions, due apparently to extensive inactivation by sunlight. Encapsulation of the virus in ethylcellulose had been shown to significantly improve field persistence.

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A pilot test was initiated (fiscal years 1975 through 1977) in which various encapsulated formulations were prepared by a research institute and initially evaluated with an exacting laboratory-greenhouse bioassay. Formulations which passed this stage were evaluated in field cages. Formulations which performed well in field cages were evaluated in small field plots and finally in large plots of 10 to 20 acres. This project yielded a formulation which performs well for 2 weeks and which is now being evaluated in several States by industrial and public sector scientists. Formulations containing either carbon black or titanium dioxide proved effective in protecting the virus from light, adverse acidity, and high temperatures. A total of \$228,000 over 3 years was allocated to this project from the Administrator's Pilot Test Fund.

Field Evaluation of Feasibility of Controlling Caterpillars with  
Autographa californica Virus

Principal Investigator: A. M. Heimpel  
Beltsville, Maryland

A multiple embedded virus which attacks caterpillars in eight families of the order Lepidoptera was isolated from the alfalfa looper by an Agricultural Research Service scientist. Preliminary studies showed that the virus killed the cabbage looper, alfalfa looper, soybean looper, corn earworm, tobacco budworm, fall armyworm, pink bollworm, cotton leaf perforator, saltmarsh caterpillar, diamond backed moth, and velvet-bean caterpillar. A total of \$97,115 was allocated during fiscal years 1975 through 1977 for a pilot test to facilitate the development of the virus. The objective of the pilot test was to assess the feasibility of producing, formulating, and applying the virus to attain practical control of pests on cabbage, cotton, and soybeans.

Certain formulations gave good control of loopers and Heliothis. However, it appears that the virus acts too slowly to adequately protect cabbage when pest densities are high.



Management of Populations of Dermestid Beetles with Sex Attractants and Pathogens

Principal Investigator: W. E. Burkholder  
Madison, Wisconsin

Dermestid beetles such as the black carpet beetle are serious pests in feed mills, grain elevators, warehouses, and food processing plants. In recent years, the sex pheromones of these pests have become available. Also, the life history and pathology of a highly virulent protozoan pathogen of these pests has been worked out. Previous studies have established that male beetles can be attracted by the pheromone to corrugated paper inoculation stations treated with a special spore formulation. These males become infected, disperse, and mix with the indigenous population and spread the disease into a multitude of niches. Preliminary work also had demonstrated that few, if any, insects survive infection, that the disease is highly contagious, and that males can be readily inoculated with pheromone-baited devices. Infected males were shown to pass the disease to females.

The pilot test (fiscal years 1975 through 1977) focused on determining optimum density of inoculation devices, site selection, and appropriate levels of spores and pheromone per device. Also, the practical limits of attracting and dispersing males were determined. Efficacy of the devices was evaluated under practical warehouse conditions and compared with currently available conventional treatments. Pest populations were reduced by more than 99 percent within two generations. Thus, the new approach appears to be practical. Additional research will be needed to register the device with the Environmental Protection Agency. This pilot test was supported with a total of \$115,000 over 3 years from the Administrator's Pilot Test Fund.

Integrated Weed Control on Sagebrush Grasslands of the West

Principal Investigators: R. A. Evans, R. E. Eckert, Jr.  
and J. A. Young  
Reno, Nevada

Millions of acres of western rangelands are degraded by infestations of sagebrush, rabbitbrush, and downy brome. Research has shown that in the sagebrush grass ecosystem, the establishment of good stands of perennial grasses can increase forage production up to 10 times, and that these

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stands resist weed populations. In fiscal year 1977, a pilot test was initiated (FY 1977 through 1981, \$349,800) to develop a practical system of weed control, seeding, and inovative grazing management.

### Integrated Control of Mesquite and Creosotebush

Principal Investigators: C. Herbel, R. Gibbens, J. Tromble,  
and H. Morton  
Las Cruces, New Mexico

Mesquite and creosotebush are now the dominant weeds on 139 million acres of once productive rangeland in the Southwest. In fiscal year 1977, a pilot test was initiated (FY 1977 through 1981, \$263,110) to evaluate combinations of herbicides, root plowing and reseeding as a basis for (a) obtaining estimates of range improvement costs, (b) determining livestock production on improved ranges, (c) assessing environmental impacts including affects of herbicides on various trophic levels, and (d) providing data for formulation and simulation modelling of grazing and management strategies to maximize livestock production and to maintain weed-free ecosystems.

### Total Weed Population Management for Irrigated Agriculture

Principal Investigator: E. E. Schweizer  
Ft. Collins, Colorado

Weeds are a major pest of irrigated crops, in part, because irrigation waters facilitate the dissemination of seeds and other propagules. A system of total population management is needed to inexorably reduce the tremendous weed seed reserves in the soils of irrigated farms. For the seven principal genera of weeds in irrigated farms in Colorado, the number of weed seeds per acre ranges from 1,500,000 to 3,200,000.

In fiscal year 1975, a pilot test was initiated (FY 1975 through 1978, \$140,728) in order to compare the costs and benefits of a total weed population management system versus what is commonly accepted as good farmer practice.

The total population management system consists of (a) use of weed-free crop seed, (b) use of screens to remove seeds and other propagules

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from irrigation water, (c) control of all weeds on ditchbanks by flaming or cultivation, and (d) the use of herbicides on an "as needed" basis. In the standard system, herbicides are used routinely along with cultivation to the extent that it can be accomplished by the farm manager.

The greatest reduction in weed seeds has occurred in the continuous corn system, with 36.2 percent for total population management and 53.2 percent for accepted farmer practice. In rotational cropping systems, the decrease in the total number of weed seeds per acre has been 29.5 percent for the total population management and 21.9 percent for good farmer practice. These results indicate the strong action of powerful herbicides such as atrazine that can be used with continuous corn but which cannot be used as extensively when crops are rotated.

It appears the original objectives may not be fully attained by the end of FY 1978.

### Integrated Control of Wild Oat in Various Crop Rotations

Principal Investigator: J. Nalawaja  
Fargo, North Dakota

The project was initiated in fiscal year 1975 and involves integrated combinations of cultural, mechanical and chemical techniques applied to large fields at four locations in North Dakota. Each location has seven different 4-year rotations on 10-acre individual plots. The primary objective is to establish 4-year rotations of practices for each region of the State capable of reducing heavy wild oat infestations to levels which do not reduce crop yields. This level is in the range of 0 to 10 wild oat plants per square yard. Previous studies had shown that each method when used alone reduced the wild oat population. However, a practical system of methods to control the pest had not been developed for use in the cropping systems used in various regions of the State.

After 2 years of experimentation, the wild oat reserve has declined as much as 88 percent at Penn, and as much as 61 percent at Williston in some rotations. At Fargo, the wild oat seed reserve declined only in treatment combinations which gave more than 95 percent control. A total of \$143,426 was provided for this pilot test from the Administrator's Pilot Test Fund.



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Control of Aquatic Weeds with Plant Competitors

Principal Investigator: P. Frank  
Davis, California

Submerged and rooted aquatic weeds are a major problem in irrigation canals, ponds, lakes, and reservoirs. A nonchemical method is needed to control such weeds in order to avoid the repeated addition of expensive chemical herbicides to water. Studies in California have established that natural growths of the tiny plants, slender spikerush, and barked spikerush, suppress the growth of aquatic weeds in several canals and reservoirs.

A pilot test was initiated (fiscal years 1975 through 1977) to determine the feasibility of establishing moderate-scale plantings of spikerushes in canals to control submerged rooted aquatic weeds. This pilot test was intended to (1) develop methods of producing, harvesting, and storing large quantities of seeds and tubers and of disseminating and planting the propagules, and (2) to identify ways of facilitating the effectiveness of the spikerushes in displacing weeds.

Methods of harvesting, storing, disseminating, and planting the propagules have been developed. Plots ranging in size of 1 to 20 acres will be established in a reservoir and in a canal.

A total of \$36,420 has been allocated for this test from the Administrator's Pilot Test Fund. However, it appears that additional time and funding will be required to fully attain the original objectives.



